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THE COMMERCIAL GRANITES OF NEW ENGLAND

BY

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THE COMMERCIAL GRANITES OF NEW ENGLAND.

By T. Nelson Dale.

INTRODUCTION.

This work is a revised and abridged edition of the writer's four bulletins and two supplementary papers on the commercial granites of the States of New England.[1] The exhaustion of the edition of some of these bulletins and the duplication of the general treatment of granite involved in any reprint of the originals make such a combination and revision advisable. The revision has also permitted greater systematization in the introductory part, as well as the correction of some errors in both parts. The descriptions of quarry plants, which change from year to year, have been omitted; also the purely technologic details, which belong properly to the province of the Bureau of Mines.

A small area of white granite in Plymouth, Vt., not mentioned in Bulletin 404, has been visited, and its granite is here described. The granites of quarries opened in Woodbury, Vt., and Milford, Otis, Stoughton, Cohasset, and Braintree, Mass., since the publication of Bulletins 404 and 354 are described.

As in the original bulletins, the general aim of this one is to present the subject in both its economic and its general scientific aspects and to make the scientific part intelligible to the general reader. The economic part includes a chapter on the adaptations of New England granites and another on the economic geologic factors in granite quarrying, with some practical suggestions.

A number of abandoned quarries are described with the active ones, either because of the scientific interest of their granite or their rock structure or because of their latent economic possibilities.

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[1] Dale, T. N., The granites of Maine, with an introduction by George Otis Smith: U. S. Geol. Survey Bull. 313, 1907; The chief commercial granites of Massachusetts, New Hampshire, and Rhode Island: U. S. Geol. Survey Bull. 354, 1908; The granites of Vermont: U. S. Geol. Survey Bull. 404, 1909; Supplementary note on the granites of New Hampshire. U. S. Geol. Survey Bull. 430, pp. 346–372, 1910; Supplementary note on the granites of Massachusetts: U. S. Geol. Survey Bull. 470, pp. 240–288, 1911. Dale, T. N., and Gregory, H. E., The granites of Connecticut: U. S. Geol. Survey Bull. 484, 1911.

The word "granite" in the title is used in its commercial sense and thus includes, besides true granites, quartz monzonite, granite gneiss, diorite, diorite gneiss, gabbro, diabase, and norite. The scientific name is always given.

The specimens described from active quarries were always selected by the foreman or operator of the quarry. The number of each specimen described, to which that of the thin section or sections corresponds, is given, so that the description can be verified by consulting the collections at the National Museum.

The word "coarse," applied to the texture of granite, includes that with feldspars over 0.4 inch in diameter; "medium," with feldspars under 0.4 inch and over 0.2 inch; "fine," with feldspars under 0.2 inch.

All the granites described are classified according to their characteristics of texture, color, and uses on pages 419–435, with their commercial and scientific names. A bibliography of the economic geology of granite is given on pages 464–467. It includes several works of a general character besides papers on physical tests and geometric analyses of granite, and on the statistics of granite production in the United States. A short list of more or less elementary text books on mineralogy and igneous rocks will be found on page 97, and a glossary of such scientific terms as have been unavoidably used and of quarry terms on pages 467–471. Miss Altha T. Coons, of this Survey, contributes the statistics of production.

The section by George Otis Smith on the occurrence of granite in Maine, including its geographic distribution and its geologic relations, formed his introduction to Bulletin 313. The passages on the geologic history of Connecticut, the distribution of granite and gneiss in that State, and on the nature of its granitic intrusions have been taken entire from Herbert E. Gregory's contribution to Bulletin 484. Similar but shorter quotations from other geologists as to other States are duly credited.

The writer's obligation to Albert Johannsen for the critical revision of the more difficult microscopic mineral determinations is renewed here. Chemical determinations by W. T. Schaller and George Steiger of this Survey, by E. C. Sullivan, and by George P. Merrill, of the United States National Museum, and a complete mineral analysis by Wirt Tassin, also of the National Museum, are credited in their place. The Rosiwal method of estimating mineral percentages in rocks has been applied as far as practicable to all the types of granite described.

PART I.—SCIENTIFIC DISCUSSION.

GRANITE PROPER.

GENERAL FEATURES.

DEFINITION.

Granite, in a general sense, is essentially an entirely crystalline igneous rock, consisting mainly of quartz, potash feldspar, and a feldspar containing both soda and lime, in some granites microscopically combined, and containing also a small amount of either white or black mica or both, and in places of amphibole (hornblende, riebeckite), more rarely of pyroxene (augite, aegirite), or both. Where granite has, subsequent to or during its crystallization, been subjected to pressure sufficient to produce a parallelism in the arrangement of its minerals—that is, a schistosity—it is called gneiss or granite gneiss; but as some sedimentary rocks in becoming crystalline also possess this parallelism and closely resemble a granite gneiss they are distinguished by the term "sedimentary gneiss."

ORIGIN.

Granite is now regarded as the product of the slow cooling and crystallization of molten glasslike matter at a dull-red heat—matter which contained superheated water and was intruded from below into an overlying mass of rock of sufficient thickness not only to prevent the rapid cooling and general extrusion of the molten matter at the surface but also to resist the pressure of the intrusive by its cohesion and powerfully to compress the molten matter by its gravity. As carbonic acid can be liquefied only under pressure, its presence in liquid form within some of the microscopic cavities in the quartz of granite is alone evidence that the rock was formed under pressure. That the temperature at which granite solidified was comparatively low has been inferred from the fact that it contains minerals which lose their physical properties at temperatures higher than dull-red heat. The relations of the mineral constituents of granite to one another show the order in which they must have crystallized. This order differs from that in which they would crystallize if molten in a dry state, but laboratory experiments have shown that the presence of even a small quantity of water suffices to change that order of crystallization. The presence of superheated water in the formation of granite, inferred from the arrangement of its minerals, shows that the conditions requisite to its formation included not only the pressure of an overlying mass of rock but also expansive pressure from below. Had this molten matter been extruded at the surface it would have cooled so rapidly that but few of its constituent mole-

cules would have had time to arrange themselves in geometric order. The process of crystallization would have been arrested by the sudden passage of the material into the solid state, and the product would have been a volcanic glass somewhat resembling that which forms cliffs in Yellowstone National Park. In granite, however, the mass has cooled slowly enough to permit the complete crystallization of the originally molten glasslike matter, and no unarranged molecules remain. The production of a glass by the rapid cooling of the surface of a granitic intrusion in consequence of its contact with a schist mass is seen at Bethel, Vt., and shown in thin section in figure 9.

From observations in Norway, Colorado, Utah, Arizona, and Montana geologists conclude that the thickness of the rock overlying this molten matter may have been only a few hundred yards, the essential conditions for the production of granite being slow cooling and the confinement of the vapor of water escaping during crystallization to the adjacent rocks.[2]

Lacroix, in his studies of Mount Pelée, found that quartz may crystallize in a superficial volcanic dome, even under a thin solidified crust, as soon as this forms a closed vessel.[3]

The overlying rock mass which furnished a part of the pressure required to form granite has at many places been removed from it by erosive processes that operated through great stretches of time. Indeed, it is only by the removal of this mass that granite is anywhere naturally exposed. Although this mass may have measured hundreds of feet in thickness, its former presence is at some places attested only by a thin capping on the granite or by fragments which the lacerating action of the intruding granite has incorporated into itself.

The lacerating effect of an intrusion and the subsequent erosion of some of the overlying strata have been reproduced experimentally.[4]

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[2] Brögger, W. C., Die geologischen Verhältnisse der Pegmatitgänge des Christianiagebietes: Zeitschr. Krystall. (Groth), Leipzig, p. 225, 1890. Cross, Whitman, The laccolitic mountain groups of Colorado, Utah, and Arizona: U. S. Geol. Survey, Fourteenth Ann. Rept., pt. 2, pp. 230, 238, 1894. See also Barrell, Joseph, Geology of the Marysville mining district, Mont., a study of igneous intrusions and contact metamorphism: U. S. Geol. Survey Prof. Paper 57, 1907.

[3] Lacroix, Alfred, La Montagne Pelée et ses éruptions, p. 517, Paris, 1904.

[4] Howe, Ernest, U. S. Geol. Survey Twenty-first Ann. Rept., pt. 3, pp. 294–296, pl. 43, 1901. Reyer, of the Austrian Geological Survey, has illustrated a granite intrusion by this simple experiment: Upon a table a frame of clay, say 2 inches thick, is constructed about a square piece of board 1 inch thick. After removing the board a mixture of medium-thick plaster and red coloring matter is poured into the inclosure. The surface of the red plaster is then sprinkled with a layer of white plaster powder. After making a lens-shaped perforation in the center of the board it is again fitted into the frame and pressed against the red and white layers until the white plaster exudes through the opening, and afterward the red intrudes the white. The materials are allowed to harden and are then sawn to show the structure. See Reyer, Ed., Tektonik der Granit Ergüsse von Neudeck und Carlsbad, etc.: K.-k. geol. Reichsanstalt Jahrb., vol. 29, pp. 432–433, fig. 6, 1879.

Granite itself has been converted in the laboratory into a material which upon cooling under ordinary conditions has proved to be a glass, and the chief mineral constituents of granite have been artificially crystallized at high temperatures in the presence of water vapor under high pressure, but the conditions requisite for the production of a granitic rock from its chemical constituents have not yet been successfully imitated.

Some granite shows locally a certain alinement of its mica plates and feldspars, due to the flow of the mass while it was in a plastic state—a structure which was probably controlled by the pressure and form of the bordering rock. This "flow structure" should not be confounded with the schistosity, which is due to later pressure, involves mineral changes, and is usually regional rather than local in extent, and which is called "gneissic structure."

The great differences in the grade of texture in granites—the mineral particles ranging from an average diameter of 0.02 inch (0.5 millimeters), and even 0.0069 inch (0.175 millimeter), to over 0.5 inch—is attributed to differences in the rate of cooling. The portions at the margins of large masses, or in small masses such as dikes, which cooled rather quickly, crystallized in very small crystals; the central portions, which cooled more gradually, became coarsely crystalline.

MINERAL COMPOSITION.

Feldspar is the most conspicuous and generally the most abundant mineral in granite. By its color or colors it usually determines to a large extent the general color of the rock, and by the light which it reflects it gives brilliancy. It is easily distinguished from the other constituents by its smooth cleavage surfaces and milky, bluish-white or opalescent, reddish, brownish, or greenish color. Granite usually contains two kinds of feldspar, the more abundant of which is generally potash feldspar, a silicate of alumina and potash. This occurs in one or both of two crystal forms, orthoclase or microcline, which, however, can be distinguished only by means of the microscope. The other variety of feldspar (plagioclase), containing either soda or soda and lime, although it may be of the same color as the potash feldspar, can in some granites be distinguished by the very fine parallel lines on its surface. Usually it differs greatly in color from the potash feldspar, which may be reddish, brownish, or lavender-colored; the plagioclase may be white, gray, or greenish. Under the microscope the soda-lime feldspar can be readily distinguished from the potash feldspar by its behavior in polarized light, which brings out its crystalline structure and indicates its particular variety and approximate chemical composition. A granitic rock that

contains the two feldspars in equal proportions is distinguished by a special technical name.

Quartz (silica), the next most abundant constituent, is readily recognized by its glassy luster, uneven fracture, and brittleness. It may be clear, milky, bluish, opalescent or amethystine, or smoky. The quartz determines in some measure the shade of the rock. The vitreousness of the quartz greatly affects the granite.

The next most abundant constituent of granite is mica, which is present in two forms—the white (muscovite, or potash mica), essentially a silicate of alumina with potash and minor amounts of soda and ferrous oxide, and the black (biotite, or magnesia mica), essentially a silicate of alumina with potash, magnesia, and both ferric and ferrous oxide. Granite may contain one or both of these micas. The dimensions and number of the scales of black mica largely determine the shade of many granites.

Amphibole, a constituent of many granites, although greenish (rarely bluish in minute or very thin crystals), may in crystals of ordinary size appear as dark as the black mica, but, unlike that mineral, it does not split into scales. Amphibole and pyroxene resemble each other so closely when in small particles that they can be distinguished only by means of the microscope. Both may occur in granite.

In addition to these more abundant minerals, others are usually present in minute or microscopic quantities. Some of these including kaolin, sericite (a potash mica or muscovite), chlorite, epidote, zoisite, and calcite, as well as paragonite (soda mica), which may possibly be present, are the result of chemical changes in the feldspars or the biotite or amphibole and are therefore called "secondary." Others, like zircon, apatite, titanite, rutile, tourmaline, fluorite, garnet, magnetite, molybdenite, ilmenite, pyrite, and allanite, are regarded as original "accessory constituents." Calcite also occurs in microscopic quantity as an original mineral of some granites.[5] Of these minor accessories, pyrite (iron disulphide) and calcite (lime carbonate) alone have economic significance, for these may discolor or weaken the stone when dissolved or oxidized on an exposed surface.

The chemists of this Survey have treated 10 granites from Maine, 23 from Massachusetts, New Hampshire, and Rhode Island, and 10 from Vermont, with hot dilute acetic acid and find that they contain from 0.05 to 2.46 per cent of $CaCO_3$ (lime carbonate).

The following accessory minerals have been detected in the New England granites: Garnet, tourmaline, zircon, titanite, magnetite,

[5] See Zirkel, F., Petrographie, vol. 2, p. 13, and Weinschenk, E., K. Bayer. Akad., Math.-phys. Classe, Abh., vol. 18, p. 730, pl. 5.

ilmenite (?), pyrite,[6] molybdenite, fluorite, apatite, biotite, allanite, and rutile; also the secondary minerals hematite, limonite, calcite, kaolin, muscovite, paragonite (probably), quartz, hornblende, riebeckite, chlorite, epidote, and zoisite. The number of minerals occurring in the pegmatite dikes within the same granites is very much larger. (See pp. 46, 47.)

The arrangement of the chief minerals in the stone is described under the heading "Texture" (p. 10).

The percentages of the mineral constituents differ within wide limits in granites from different localities. The percentages of muscovite and of the ferromagnesian minerals (biotite, amphibole, pyroxene) are always small; those of the feldspar and quartz are large. There is considerable variation in the relative amounts of feldspar and quartz and still more in the amounts of each of the feldspars.

CHEMICAL COMPOSITION.

The chemical composition of granite is of less scientific and economic significance than its mineral composition, for, although chemical analysis shows the percentages of the constituent elements, the process by which these are determined necessarily mingles the elements of several minerals whose proportions vary and whose contributions to the physical properties of the rock differ greatly. When, however, a combination of elements occurs only in one or two of the minerals the chemical analysis serves to corroborate the evidence obtained by microscopic analysis.

Many analyses of granite have been published, but it will suffice here to give the extremes of the percentages shown by some of the more authoritative of these and to refer the reader to works containing complete analyses.[7] Four analyses of granites from Scotland, Ireland, Italy, and Sweden show the following ranges:[8]

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[6] As to the question whether marcasite (white iron pyrites) occurs in granite, Allen, Crenshaw, and Johnston, in an important paper on "The mineral sulphides of iron" (Am. Jour. Sci., 4th ser., vol. 33, pp. 169–236, 1912), state on page 216 that "the fact that marcasite never occurs as a primary constituent of magmas, while pyrite sometimes does, is explained by the fact that marcasite can not exist above 450°." On p. 190 they add: "Paramorphs of pyrite after marcasite are certainly possible, but paramorphs of marcasite after pyrite are evidently impossible." J. D. Dana, in the fourth edition of his System of mineralogy (1858, p. 61), stated that "At Warwick, N. Y., marcasite occurs in simple and compound crystals in granite with zircon." This passage is repeated verbatim in the sixth edition, 1911, p. 95.

[7] See Washington, H. S., U. S. Geol. Survey Prof. Paper 99, 1917; also Clarke, F. W., U. S. Geol. Survey Bull. 419, 1910.

[8] Geikie, Archibald, Textbook of geology, 4th ed., vol. 1, p. 207, London, 1903.

Analyses of European granites.

Silica (SiO_2)	70.60–74.82
Alumina (Al_2O_3)	14.86–16.40
Ferric oxide (Fe_2O_3)	.10– 1.63
Ferrous oxide (FeO)	.42– 3.20
Magnesia (MgO)	.14– 2.23
Magnesia (MgO)	.23– 1.00
Lime (CaO)	.89– 2.47
Soda (Na_2O)	3.51– 6.12
Potash (K_2O)	3.55– 5.10

Twelve analyses, made at the laboratory of the United States Geological Survey, of granites from California (2), Colorado (1), Maryland (3), Michigan (1), Minnesota (1), and Montana (4) show the following ranges:[9]

Analyses of American granites.

Silica (SiO_2)	63.87–76.10
Alumina (Al_2O_3)	12.95–19.13
Ferric oxide (Fe_2O_3)	.00– 1.80
Ferrous oxide (FeO)	.42– 3.20
Magnesia (MgO)	.14– 2.23
Lime (CaO)	.12– 4.30
Soda (Na_2O)	2.36– 4.53
Potash (K_2O)	1.87– 7.99
Titanium dioxide (TiO_2)	.07– 0.65
Phosphoric acid (P_2O_5)	Trace– 0.30

The average of 21 analyses of even-grained Georgia granites made by Watson[10] yields the following percentages:

Analyses of Georgia granites.

Silica (SiO_2) (extremes 68.38, 72.56)	69.97
Alumina (Al_2O_3)	16.63
Ferric oxide (Fe_2O_3)	1.28
Lime (CaO)	2.13
Magnesia (MgO)	.55
Soda (Na_2O)	4.73
Potash (K_2O)	4.71

Holmquist[11] gives 137 analyses of Swedish granites arranged in a continuous table.

In all these analyses most of the lime is to be attributed to the lime-soda feldspar and nearly all the rest of it to apatite (lime phosphate), or to amphibole and pyroxene, if these are present.

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[9] See U. S. Geol. Survey Bull. 419, p. 33, analyses C, D, E; p. 46, analysis A; p. 52, analysis D; p. 77, analyses D, E, F; p. 86, analysis C; p. 99, analysis E; p. 151, analysis A; p. 157, analysis E.

[10] Watson, T. L., Georgia Geol. Survey Bull. 9–A, p, 241, 1902.

[11] Holmquist, P. J., Studien über die Granite von Schweden: Upsala Univ. Geol. Inst. Bull., vol. 7, Nos. 13 and 14, pp. 77–269, 1906.

It is of interest to note in this connection that certain Scotch and Irish granites contain from 1.6 to 2.8 volumes of gas per volume of rock. This gas is inclosed in microscopic cavities within the minerals, and in the Scotch granite it consists of carbon, oxygen, hydrogen, and nitrogen in the following combinations and proportions: CO_2, 23.60; CO, 6.45; CH_4, 3.02; N_2, 5.13; H_2, 61.68[12]

R. T. Chamberlin[13] found in a gray granite from Quincy, Mass., 1.60 volumes of gas per volume of rock and made up as follows: CO_2, 0.39; CO, 0.09; CH_4, 0.06; H_2, 1.04; N_2, 0.02. Averaging 19 analyses of granites and granite gneisses (17 by himself and 2 by Gautier) he obtained the following volumes of each gas per volume of rock: CO_2, 1.47; CO, 0.22; CH_4, 0.05; H_2, 1.36; N_2, 0.09—total, 3.19.

TEXTURE.

Definition.—The texture of a rock signifies the size, the forms, and the mutual relations of its minerals as seen without or with a microscope.

Character and grade.—The most characteristic external feature of granite is the character of its grain. Some granites are even grained; others contain more or less thinly disseminated and complete crystals of feldspar in a mass of finer, even-grained material—that is, they show what is called porphyritic texture. (See p. 10.) The next most striking feature is the relative coarseness or fineness of grain in an even-grained granite. Three grades of texture of this sort may be distinguished—(1) coarse, in which the feldspars generally measure over 1 centimeter, or 0.4 inch; (2) medium, in which they measure under 1 centimeter (0.4 inch) and over 0.5 centimeter (0.2 inch); (3) fine, in which they measure under 0.5 centimeter (0.2 inch). In some coarse-grained granites the feldspars measure one or several inches, and in some fine-grained ones all the particles range from 0.25 to 1 millimeter (0.04 inch) in diameter, and some average as low as 0.5 millimeter or (0.02 inch). Extremely fine ones average 0.175 millimeter or about 0.007 inch.

Forms of minerals.—Even without the aid of the microscope it will be noticed that, except in granites of porphyritic texture, the minerals rarely attain their complete crystalline form. They have interfered with one another's growth. It will also be noticed that some of the crystals of feldspar in some granites are surrounded by a border of a different feldspar. Thus a red feldspar may be bordered by a white or greenish one, or vice versa. Either of these may be the potash feldspar and the other a soda-lime feldspar. It will also be noticed that many of the feldspars are not simple incomplete or complete

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[12] Tilden, W. H., Roy. Soc. London Proc., vol. 60, pp. 454, 455, 1897.

[13] Chamberlin, R. T., The gases in rocks: Carnegie Inst. Washington Pub. 106, p. 23, 1916.

crystals, but "twins," having the cleavage planes in one half at a different angle from those in the other half, so that when held in the sunlight only one half will reflect the light in one position.

Arrangement of minerals.—A polished surface of any medium or coarse grained granite shows that the quartz fills up the spaces between the feldspars—that is, it was formed after them—also that both feldspars and quartz inclose particles of mica, etc., which must therefore have crystallized before them. Under the microscope the arrangement of the minerals is found to be such that they must usually have crystallized in the following order: Magnetite, pyrite, apatite, zircon, titanite, amphibole and pyroxene, biotite, muscovite, the feldspars, and, last of all, the quartz. It should be noted, however, that many of the feldspar crystals contain intergrown quartz, so that some of the quartz must therefore have crystallized at the same time as the feldspar. The structure of the potash feldspar in some granites is very intricate, as it contains microscopic intergrowths of a lime-soda feldspar, both having evidently crystallized at the same time or in close alternation. Also, as stated above, the potash feldspar may be rimmed with soda-lime feldspar, or vice versa.

Porphyritic texture.—In some granites some of the minerals, generally the feldspars, occur as large, isolated, more or less complete crystals in a mass (groundmass) of finer, even-grained granite. This is known as the porphyritic texture. (See Pl. XXXI, *B*.) The conditions under which a porphyritic granite was formed are not yet perfectly understood. The large crystals were, of course, formed before the completion of the groundmass. If a porphyritic granite passes into a gneiss, the large crystals become elongated and lens-shaped and the rock is called a porphyritic or "augen" (eyes) gneiss. (See Pl. XXXI, *A*.) The secondary structure known as gneissic is described on page 65.

COLOR.

The color of a granite is almost entirely governed by that of its dominant feldspar, and its shade is largely determined by that of its quartz and its mica. These physical qualities of granitic feldspar and quartz are described on pages 75–79, 80, 81.

PHYSICAL PROPERTIES.

Granite derives its physical properties from its mineralogic constitution, particularly from its large content of feldspar and quartz, and from its texture. Among these physical properties the most important are weight, cohesiveness, elasticity, flexibility, hardness, expansibility, porosity, and vitreousness.

Weight.—In order to establish a fixed standard the weight of a certain volume of a rock is compared to that of an equal volume of

distilled water. The weight thus determined is called the specific gravity of the rock. The specific gravity of granite ranges from 2.593 to 2.731. The average of these extremes is 2.662, which is equivalent to 2 long tons, or 4,480 pounds, to the cubic yard, or about 165 pounds to the cubic foot. Geikie [14] calls attention to the change in the weight of granite when immersed in sea water, as given by Stevenson.[15] A red granite having a specific gravity in air of 2.71, or 13.2 cubic feet to the ton, will in sea water of a specific gravity of 1.028 measure 21.3 cubic feet to the ton.

Cohesiveness.—The cohesiveness of a rock is ascertained by determining its crushing strength—that is, the weight in pounds required to crush it or to destroy its cohesion. The ultimate compressive strength of granite ranges from about 15,000 to 43,973 pounds per square inch,[16] but the usual range is from 18,000 to 34,000 pounds. Herrmann [17] gives the crushing strength of European granites as ranging from 1,100 to over 3,000 kilograms per square centimeter. Recent tests by the Bureau of Standards on five granites from Maine, Maryland, and North Carolina show their compressive strengths ranging from 17,132 to 41,772 pounds per square inch.[18]

Elasticity.—Tests made at the United States Arsenal at Watertown, Mass., to determine the compressive elasticity of specimens of granite from Arkansas, Connecticut, Maine, Minnesota, and New Hampshire, show that the specimens, in a gaged length of 20 inches and a diameter of 5.5 inches at the middle, when placed under a load of 5,000 pounds to the square inch, suffered compression ranging from 0.0108 to 0.0245 inch, resulting in a lateral expansion ranging from 0.005 to 0.007 inch, and giving ratios of lateral expansion to longitudinal compression ranging from 1:8 to 1:47.[19]

The results of some experiments on the elasticity of granites from Westerly, R. I., are given by Adams and Coker.[20]

Flexibility.—Although granite contains a large amount of brittle material (estimated at 30 to 60 per cent) and the interlocking of its various particles gives to it great cohesion and rigidity, yet in sheets of sufficient thinness and areal extent it is flexible. Sheets half an inch thick and 4 feet long may be bent, as noted in the description

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[14] Textbook of geology, 4th ed., p. 568.

[15] Stevenson, T., Harbours, p. 107.

[16] These extremes are from Wisconsin granites. See Buckley, E. B., On the building and ornamental stones of Wisconsin: Wisconsin Geol. and Nat. Hist. Survey Bull. 4, pp. 361, 390.

[17] Hermann, O., Steinbruchindustrie und Steinbruchgeologie, p. 43.

[18] Figures from the Director, Oct. 11, 1916.

[19] Report of the tests of metals, etc., made with the United States testing machine at Watertown Arsenal, Mass. (1895), pp. 339–348, 1896.

[20] Adams, F. D., and Coker, E. G., An investigation into the elastic constants of rocks, more especially with reference to cubic compressibility: Carnegie Inst., Washington Pub. 46, 1906. For another reference to the compressibility of Westerly granite see Adams, F. D., An experimental contribution to the question of the depth of the zone of flow in the earth's crust: Jour. Geology, vol. 20, pp. 112–115, 1912.

of the Lawton quarry, at Norridgewock, Maine (p. 256). Whether flexibility in this granite was conditioned upon a slight loosening of the grains by chemical and physical change is uncertain.

Hardness.—As will be seen by reference to the tests for hardness described on page 100, granites differ greatly in hardness. This difference is due not merely to differences in the percentage of quartz but also to variations in the character of the feldspars.

Expansibility.—The expansibility of granite has been variously tested. Bartlett[21] found that a piece of granite coping 5 feet long, subjected to a winter temperature of 0° F. and a summer temperature of 96° F., expanded 0.027792 inch, or 0.000004825 inch per inch of length for each degree of increase in temperature. The Ordnance Department at the Watertown Arsenal,[22] tested the granites referred to under the heading "Elasticity" and found that slabs of gaged lengths of 20 inches in passing from a cold-water bath at 32° F. through a hot-water bath at 212° F. and back again to cold water at 32° F. expanded from 0.0017 to 0.0059 inch, averaging 0.0040 inch.

Porosity.—Granite contains and absorbs water, which is held in microscopic spaces both within and between its constituent minerals. Ansted[23] states that granite generally contains about 0.8 per cent of water and is capable of absorbing about 0.2 per cent more. In other words, a cubic yard of granite weighing 2 tons contains in its ordinary state about 3½ gallons of water and can absorb nearly a gallon more on being placed in pure water for a short period. Buckley[24] found that the pore space or porosity in fourteen Wisconsin granites ranges from 0.17 to 0.392 per cent, and that the ratio of absorption (percentage of weight of absorbed water to the average dry weight of the sample) of the same granites ranges from 0.17 to 0.50. The Bureau of Standards finds that this percentage in a North Carolina and a Maryland granite ranges from 0.15 to 0.43.[25] Merrill[26] has shown that certain Maryland granites absorb from 0.196 to 0.258 per cent of water after drying 24 hours at 212° F. and then being immersed for 24 hours.

Vitreousness.—The vitreousness of granite is due to that of its contained quartz. Under extreme changes of temperature, as in a city fire, where water is thrown on the stone, granite exfoliates badly. This exfoliation or shelling is attributable to the unequal expansion or contraction of the outer and the inner portions of the rock under sudden changes of temperature. It is also probably connected

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[21] Bartlett, W. C., Experiments on the expansion and contraction of building stones by variation of temperature: Am. Jour. Sci., 1st ser., vol. 22, pp. 136–140, 1832.

[22] Op. cit., p. 322.

[23] Ansted, D. T., quoted by Edward Hull, in A treatise on building and ornamental stones of Great Britain and foreign countries, p. 30, 1872.

[24] Buckley, E. B., Op. cit., p. 400.

[25] Figures from the Director, Oct. 11, 1916.

[26] Merrill, G. P., Maryland Geol. Survey, vol. 2, pp. 94, 95.

with the vitreousness of the quartz. The unequal expansive ratios of the different constituent minerals would result in general disintegration, not in exfoliation. (See further under "Fire test," p. 102.)

Buckley [27] subjected 2-inch cubes of five Wisconsin granites to high-temperature tests and found that they were all destroyed at 1,500° F. One of them cracked at 1,000°; two others began to disintegrate at 1,200°. The most notable change was that "when struck with a hammer or scratched with a knife they emitted the sound peculiar to a burnt brick." Cutting [28] applied a fire test to granites from eighteen quarries in Maine, Maryland, Massachusetts, Minnesota, New Hampshire, Vermont, and Virginia, with the result that after saturation they all stood a temperature of 500° F. without damage but showed the first appearance of injury at 700°–800° and were rendered worthless at 900°–1,000°. Twenty-three sandstones subjected to the same tests showed the first appearance of injury at 800°–900° and became worthless at 950°–1,200°. His general results agree with those of experience as to the relative fire endurance of granite and sandstone.[29] The behavior of granite under very high temperature is not attributable to any one physical property. The physical properties of granite are further discussed in Part II, under the heading "Tests of granite" (pp. 99–103).

CLASSIFICATION.

The varieties of granite are so numerous that for either scientific or economic purposes they need to be classified.

Scientific classification.—For scientific purposes granites may be classified according to their less essential mineral constituents—mica, hornblende, and augite. Thus a granite containing white mica is termed a muscovite granite; one containing black mica, a biotite granite; one containing both, a muscovite-biotite granite. A granite containing black mica and hornblende is called a biotite-hornblende granite. Granites may also be classified according to both their mineral and their chemical composition. These two form the basis of an elaborate classification of igneous rocks, which is too complex to be outlined here.[30]

Economic classification.—For economic purposes granites may be classified first as to texture—as even grained, or porphyritic, or as coarse, medium, or fine, according to the scale given on page 9. Those of extra coarse or extra fine texture can be distinguished by the prefix "very." This scale gives five grades of textures. Gran-

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[27] Op. cit., p. 411.

[28] Cutting, H. A., Vermont Agr. Sixth Rept., pp. 47–54, 1880; Durability of building stone: Am. Jour. Sci., 3d ser., vol. 21, p. 410, 1881.

[29] Merrill, G. P., Stones for building and decoration, p. 435.

[30] See Cross, Whitman, Iddings, J. P., Pirsson, L. V., and Washington, H. S., Quantitative classification of igneous rocks based on chemical and mineral characters, with a systematic nomenclature, Chicago, 1903; also Jour. Geology, vol. 10, pp. 555 et seq., 1902.

ites should also be classified as to general color and shade—as pinkish, reddish, lavender, or gray or warm gray (that is, a gray showing the presence of a slight reddish, reddish-purplish, or yellowish tinge), and as dark, medium, or light; and the terms "dark gray" and "light gray" may be modified by prefixing the word "very." The word "shade" here is used throughout to denote degree of blackness apart from color. In very many granites this is due directly to the relative smokiness of the quartz or the amount of black mica or other very dark silicate. They may be further classified and designated by the colors of their most conspicuous minerals, the feldspars, quartz, and mica. A stone may thus be called a coarse even-grained warm-gray granite, with lavender and white feldspars, smoky quartz, and black mica; or another may be called a fine even-grained, very light gray granite, with white feldspar, clear quartz, and both white and black mica. Lastly, they may be classified by their uses—as constructional, monumental, inscriptional, polish, or statuary granites. All the commercial granites of New England will be found classified according to their uses, colors, and shades on pages 419–435. The outline of an exhaustive technical description of any granite can be constructed from the tests enumerated on pages 99–103.

GENERAL STRUCTURE.

The term "structure" embraces all the divisional planes that traverse the rock. These occur at intervals ranging from a microscopic distance to one measured by scores of feet and either cross or, very rarely, are parallel to the texture resulting from crystallization.

FLOW STRUCTURE.

Where two varieties of granite lie in contact, as at Redstone, N. H. (p. 165), and at Norridgewock, Maine (fig. 64), the dividing line between them indicates the direction of their flow, for the same reason that the direction of the flow of a stream would be shown by the demarcation between its water and that of a muddy tributary a little below their junction. In some places this direction is also indicated by streaks or sheets of mica scales parallel to the line between the granites. Such streaks, therefore, where alone, are regarded as indicating flow structure. They may be inclined at all angles or be in horizontal undulations with axes pitching 10° to 40°. In some Massachusetts and New Hampshire quarries the structure is parallel to the surface of the granite at its contact with overlying rocks or surrounds in parallel bands the surface of large inclusions. (See pp. 90, 281, and fig. 17.) Flow structure also is conspicuous in the granite of Milford, Mass., and in some of the quarries of Milford, N. H. (See pp. 185, 343.) At the Millstone quarry in Water-

ford, Conn., flow structure doubles over on itself. (See fig. 90 and p. 396.) The very local character of such structural features indicates that they are not due to pressure affecting the entire region, but that they originated while the granite masses were still plastic. A granite that exhibits flow structure is called by some writers a flow gneiss.

RIFT AND GRAIN.

DEFINITION.

The rift in granite is a feature of considerable scientific interest and of much economic importance. It is an obscure microscopic foliation—either vertical, or very nearly so, or horizontal—along which the granite splits more easily than in any other direction. The grain (see glossary) is a foliation in a direction at right angles to this, along which the rock splits with a facility second only to that of the fracture along the rift. After a little experience an observer can detect the rift with the unaided eye, where it is marked.

PREVIOUS DESCRIPTIONS.

The earliest mention of rift in geologic literature appears to be that made in 1778 by J. F. W. Charpentier,[31] who noticed that granite millstones which were cut with their largest diameter parallel to the rift were much more readily worn than those cut at right angles to it—that is, parallel to the "hard way." He attributed this property to a parallel arrangement of the mineral particles. The next reference was made in 1803 by Pötsch,[32] who described the rift in the granites of Lausitz, in Saxony. In 1833 it was referred to by Enys and Fox[33] as characterizing the granites of Penrhyn, and in 1834 it was mentioned by De la Beche;[34] also in 1855 by Adam Sedgwick,[35] who attributed it to crystalline action at the time of consolidation. In 1860 C. F. Naumann[36] ascribed it either to local differences of cohesion or to an inner strain possibly related to the direction of original consolidation. In 1864 G. vom Rath[37] described a diorite from Monte Adamello, in the Tyrol, without dominant rift, and observed that the rift course was, on the contrary, uniform in the granite of Monte Motterone (Baveno). In 1876 James D. Dana[38] stated that "granite often has a directon of easiest fracture due to the fact

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[31] Mineralogische Geographie des chursächsischen Lande, 1778. See also his Beobachtungen über die Lagerstätte der Erze, 1779.

[32] Bemerkungen und Beobachtungen über das Vorkommen des Granits in geschichtete Lagen, p. 140, 1803.

[33] London and Edinburgh Philos. Mag., 3d ser., vol. 2, pp. 321–327, 1833.

[34] Researches in theoretical geology, and Report on the geology of Cornwall, 1834.

[35] Geol. Soc. London Trans., 2d ser., vol. 3, pt. 3, p. 483, 1855.

[36] Lehrbuch der Geognosie, 2d ed., vol. 2, pp. 191–192, Leipsig, 1860.

[37] Beiträge zur Kenntniss der eruptiven Gesteine der Alpen: Deutsch. geol. Gesell. Zeitschr., vol. 16, pp. 249–260, 1864.

[38] Manual of geology, 2d ed., p. 628, 1876.

that the feldspar crystals have approximately a uniform position in the rock, bringing the cleavage planes into parallelism." This is true in those places where the directions of flow structure and rift chance to coincide, and in some porphyritic granites the porphyritic crystals are arranged with reference to the rift, but that this arrangement is not the cause of rift is shown by the fact that the feldspar cleavages usually intersect the rift face at all angles. In 1879 Reyer[39] attributed rift to an original arrangement of particles by flowage. As rift in places crosses flow structure this explanation is also inadequate. In 1893 Carl C. Riiber, in a work on the granite industry of Norway,[40] described an augite syenite with inferior rift and grain, in which the cleavage planes of the individual feldspar crystals were parallel to the two cleavages, rift and grain, of the rock. In 1894 F. Zirkel,[41] after reviewing the opinions of his predecessors, tentatively suggested that rift might be the result of conditions of strain brought about by pressure from one side only, which failed to find adequate relief in jointing. In 1913 Eduard Suess[42] expressed the opinion that horizontal rift or grain structure is the primary effect of compressive strain upon granite and that vertical rift or grain, as well as vertical joints, are secondary effects of the same strain. In 1916 John Oxaal,[43] State geologist of Norway, found that "rift is a primary phenomenon determined by the congealing of the rock and by the crystallization of the mineral constituents." This was the view of Adam Sedgwick (1855). Oxaal states further:

> There is a well-defined conformity to law as regards the orientation of the separate constituents of the rock. In labrador or larvikite the feldspars are nearly parallel to each other, and the beautiful blue opalescence in the direction ($\bar{8}01$) in feldspars appears consequently only along one direction in the rock, while in the other directions little or no play of color appears. The cleavages of the rock (rift and grain) are parallel to the cleavages of the feldspar constituents.

Two American geologists[44] have described rift minutely: Tarr presents four figures reproduced from drawings made from enlarged views of thin sections showing the rift in Cape Ann hornblende-biotite granite. These figures and his descriptions indicate microscopic faults, most of which meander across feldspar and quartz alike, although some go around the quartz particles rather than through them. In the feldspars they usually follow the cleavage.

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[39] Reyer, Ed., Tektonik der Granit Ergüsse von Neudeck and Carlsbad, etc.: K.-k. geol. Reichsanstalt Jahrb., vol. 29, p. 415, 1879.

[40] Norges Granit Industri: Norges geol. Undersogelse Aarbog for 1893, No. 12, p. 45.

[41] Lehrbuch der Petrographie, 2d ed., vol. 2, p. 52–53, 1894.

[42] Über Zerlegung der gebirgsfaldenden Kraft: Geol. Gesell. Wien Mitt., vol. 6, pp. 13–60, 1913.

[43] Norsk Granit: Norges geol. Undersökelse No. 76, pp. 210, 211, 1916.

[44] Tarr, R. S., The phenomena of rifting in granite: Am. Jour. Sci., 3d ser., vol. 41, pp. 267–272, figs. 1–4, 1891; Economic geology of the United States, p. 124, 1895. Whittle, C. L., Rifting and grain in granite: Eng. and Min. Jour., vol. 70, p. 161, figs. 1, 2, 1900.

These minute faults are lined with microscopic fragments of the mineral they traverse and some of them send off short, minute diagonal fractures on either side. After comparing this description with that given by the writer on page 58 of certain microscopic fractures in the granite at its contact with a basic dike in the Flat Ledge quarry at Rockport, and also with the writer's descriptions of rift and grain cracks it may be questioned whether the microscopic faults described by Tarr were not produced by a dike and therefore can not be rift.

Whittle gives two sketches made from polished surfaces of a well-known granite quarried by the Maine & New Hampshire Granite Co., at Redstone, N. H. One of these sketches, made from a surface running at right angles to the rift, shows quartz and feldspar grains traversed by a generally parallel set of lines corresponding to the rift planes. The lines are more numerous in the feldspar than in the quartz grains. The other sketch, made from another specimen, shows besides the rift lines another less pronounced set intersecting these at right angles. This second set corresponds to the grain. A visit made by the writer in 1906 to the quarry at Redstone, N. H., corroborated Whittle's observations.

RELATION OF RIFT AND GRAIN TO FLUIDAL CAVITIES.

General examples.—During the writer's visit to Redstone a specimen of the pink granite was obtained, with a face $4\frac{3}{4}$ by 4 inches cut and polished parallel to the "hard way"—that is, at right angles to both rift and grain; also a specimen of the green granite from the adjoining western quarry, 5 by 4 inches, cut and polished in the same way. Material for a thin section of the pink granite was also obtained, and a section $1\frac{1}{2}$ by 1 inch in area was cut at right angles to both rift and grain. The direction of the rift at the quarries was found to be horizontal, crossing the sheets, which curve in anticlinal attitude across the axis of the hill with a dip of 15° both to the east and the west, while the grain is vertical with an east-west course and corresponds with the most prominent set of joints.

A careful examination of these specimens shows rift cracks in both the feldspar and quartz of the pink granite, though they are more conspicuous in the quartz, partly because of the darkness of its shade. Grain cracks are less abundant. The green granite shows both rift and grain cracks, if anything more abundant, though not as easily seen as in the quartz of the pink granite.

The large thin section shows 12 prominent rift cracks in the quartz areas in a space of 1.2 inches measured along the grain—that is, with an average distance apart of 0.1 inch. The grain cracks are far less numerous and less continuous. Some of the rift and grain cracks are filled with secondary

fibrous mica. The quartz areas also show two intersecting sets of lines, really sheets or planes of gas or liquid inclusions, the latter with vacuoles. Many of these cavities are very irregular in outline, some having several ramifications. They all range in diameter from less than 0.00285 to 0.063 millimeter. The strike of these two sets of sheets corresponds respectively to that of the rift and grain. Some of the rift or grain cracks appear to have followed the sheets of cavities, for they coincide with them. Portions of this section are shown in figure 1.

FIGURE 1.—Camera lucida drawings of quartz areas in an enlarged thin section of biotite granite from the Redstone quarry in Conway, N. H., cut parallel to the "hard way." *A*, enlarged 62½ diameters, shows sheets of cavities and incipient cracks in both rift and grain directions. *B*, from a different quartz area, enlarged 175 diameters, shows the variation in the size of the cavities and their arrangements in both rift and grain directions. *C*, from still another quartz area, enlarged 23½ diameters, shows conspicuous rift and grain cracks, filled with fibrous white mica, coinciding here and there with the sheets of cavities, also two parallel exceptional fractures crossing the rift and grain directions diagonally. *D* shows part of one of the grain sheets of cavities of *C*, enlarged 175 diameters in order to show the shapes of the cavities. As most of these sheets of cavities in the section appear to undulate in the direction of the line of vision when placed under the microscope the outlines of all the cavities become visible only by altering the focus.

Emerson[45] in describing the granite of Becket, Mass., uses these words: "The quartz grains were full of sheets of cavities, with large moving bubbles." Washington refers to streaks of inclusions in the

[45] Emerson, B. K., The geology of eastern Berkshire County, Mass.: U. S. Geol. Survey Bull. 159, p. 73, 1899.

greenish granite of Bay View, on Cape Ann: "Gas and liquid inclusions, the latter carrying a movable bubble, are quite abundant though small and occur in streaks."[46] The movements of the vacuoles in these fluidal cavities are probably related to the Brownian movement discovered by Jean Perrin. If so, they represent the molecular motion either of the "matter" within the vacuole or of the liquid without it.[47] Tarr and Newman[48] report from their study of Missouri granites: "The study with the binocular microscope showed that the inclusions were really in planes."

At the Redstone quarry of Westerly, R. I., the quartz has cavities in sheets with rift cracks parallel to them. Sheets of cavities intersecting one another at right angles and with rift and grain cracks parallel to them were also observed in granite sections from the quarry at Becket, Mass. (p. 279); and in several other Massachusetts and New Hampshire granites the cavities are arranged in rectangular sheets. This has also been found to be true in many sections of Vermont granites. One of these from Cobble Hill, near Barre, shows quartz containing sheets of cavities with conspicuous rift cracks parallel to or coinciding with them. Some of the rift cracks polarize brightly and extend into the feldspars, where they are clearly filled with fibrous muscovite; but in other sections, cut without reference to rift or grain directions, the sheets of cavities intersect at all angles or the cavities have no apparent arrangement. Many such irregularities thus result simply from the haphazard direction of the section. For this reason probably Rosenbusch refers to their occurrence in apparently irregular groups or courses only.

In the thin section of granite from Redstone, N. H., described on page 17 some of the sheets of cavities pass uninterruptedly and without deflection from one quartz particle to another, and the rest do not appear to terminate abruptly at the edge of the particle. The passage of sheets of cavities from particle to particle without interruption or deflection can be observed also in a section (109, specimen 36, b) from the adjoining green granite of Redstone, also in one (150, specimen 38, a) from the White Mountain quarry, near North Conway, N. H. This is also the case in several sections of Quincy granite (234, specimen 79, f, from the Hardwick quarry, and 206, specimen 85, a, from the Mount Pleasant quarry, Milton) and in some (221, 228, specimen 91, f) from the quarry at Becket (Chester), Mass. There is also in all these sections a general parallelism in the sheets, which lie either in the rift or the grain direction or between

[46] Washington, H. S., The petrographical province of Essex County, Mass., I: Jour. Geology, vol. 6, p. 790, 1898.

[47] Perrin, Jean, The Brownian movement and molecular reality (translation by F. Soddy), London, 1910.

[48] Tarr, W. A., and Newman, L. M., A study of the effects of heat on Missouri granites: Missouri Univ. Bull., vol. 15, No. 27, p. 55, 1914.

these and the rift or grain cracks, but some sections also have sheets of cavities diagonal to those directions. Even sections cut parallel to rift or grain or at right angles to both usually show cavities, more or less abundant, which are without any apparent arrangement.

These facts point to the probability of an intimate relation between the arrangement of the inclusions and the rift and grain structure. If the cavities, containing water or liquid carbonic acid, or either of these in a gaseous form, in the quartz of granite, are correctly regarded as having originated at the time of the crystallization of the material of the granite, then the rift and grain structure would seem to be either original also or, if secondary, to have had its directions generally determined by those of the sheets of inclusions.

That these fluidal cavities in the quartz of granite are not the only factor in the origin of rift and grain structure is evident from the parallelism which exists between the arrangement of the mica scales and the rift of many granites. At the abandoned Hayden quarry in Milford, N. H., large porphyritic crystals of biotite have their cleavage parallel to the rift. The detection of this arrangement of the mica is the principal means of determining the course of the rift before actual experiment. Similarly the course of the "hard way" in a quarried block is ascertained by the greater roughness of the particles to the touch on the "hard way" side than on either of the others.

The observations of Riiber and Oxaal in Norway on the relation of the arrangement of the feldpars in porphyritic granite to the rift fall in with the facts as to the arrangement of the mica (see p. 16), and so also does the statement of the Cornish granite quarryman [49] as to the granite quarried at Colcerrow, in Cornwall, having its large feldspars (2 by 0.5 inch) with their long axes parallel to the rift and the short ones to the "hard way." The porphyritic feldspars in the granite of Woodbury, Vt., show a parallelism in their arrangement in the groundmass (p. 146).

That any alinement of the mica scales in the direction of the sheets of fluidal cavities and the rift cracks is not necessarily identical with their arrangement or that of the feldspar by flow structure is shown by the following observations in New England granite quarries: At Mount Waldo, Frankfort, Maine, flow structure strikes N. 20° W., rift is horizontal, and grain vertical with N. 85° W. course. At the Tayntor quarry, Hallowell, Maine, flow strikes N. 35° W., rift is horizontal, and grain is vertical with N. 70° W. course. At North Jay, Maine, flow is horizontal in undulations 20 feet wide and rift is horizontal without grain. At Dodlin Hill, Norridgewock, Maine, rift is horizontal, flow and grain are both vertical with N. 60° E.

[49] See U. S. Geol. Survey Bull. 484, p. 46, 1911.

course. The norite at the Hall quarry, near Baileyville, Maine, has horizontal sheet, flow, and rift structure.

At Milford, N. H. (p. 343), flow varies greatly (N., N. 15°, 20°, 50°, 70° E., and N. 75°–80° W.), rift is horizontal or nearly so, and grain is about vertical with N. 60°–90° W. and 80° E. course. At the Klondike quarry, in Charlestown near Bradford station, R. I., flow is N. 10°–20° W., dipping west, intersecting a feeble horizontal rift. At Milford, Mass., there is a wide range in both strike and dip of flow, but rift is everywhere reported as horizontal and grain as vertical with N. 40°–90° E. course. In places flow and rift are parallel (p. 344).

Fluidal cavities in granite gneiss.—The following observations were made in studying the New England granites: An augite diorite gneiss with a vertical foliation overlying an intrusive quartz monzonite at Milford, N. H. (see Pl. VIII, A), has sheets of fluidal cavities intersecting each other at right angles. An inclusion of granite gneiss in the quartz monzonite of Blue Mountain, in South Ryegate, Vt., has parallel sheets of fluidal cavities passing from one quartz grain to another at right angles to the foliation of the gneiss. A finely banded gneiss at Old Lyme, Conn., cut by dikes of coarse pegmatite, has its quartz laminae crossed by sheets of cavities, with rift cracks parallel to them and to the gneissic foliation, crossed at right angles by a sparser and finer set of cracks. Sheets of fluidal cavities and rift cracks parallel to or coinciding with them were observed in the mica diorite gneiss of Greenwich and Torrington, Conn., also in the granite gneiss of Norwalk, Ansonia, Roxbury, Benvenue, Stony Creek, Hoadly Point, Leete Island, Sachem Head, Waterford, and Bolton, Conn. Rift in these Connecticut gneisses was always found parallel to the foliation, but in the gneiss of Selden Neck, in Lyme, which has biotite lenses with their longer axes transverse to the gneissic foliation, the rift is parallel to the long axes of the lenses and at right angles to the foliation; also in the banded gneiss of the McIntosh quarry, near Groton, Mass., the rift is transverse to the foliation, both rift and grain fractures being smoother than those along the banding.

A banded biotite granite gneiss obtained by the writer in 1913 from a conspicuous hill in the southeast corner of Peru, in Bennington County, Vt., consists of bands of feldspar grains alternating with bands of strained quartz grains whose longer axes are about at right angles to the bands. The feldspar bands carry biotite scales with their longer axes parallel to the bands. Sheets of fluidal cavities and rift cracks cross the quartz bands at right angles unaffected by the straining, but stop at the feldspar bands.

The question arises whether the sheets of fluidal cavities crossing the gneissic foliation were formed before or during the alteration

of the granite to gneiss. If the quartz individuals of the granite were greatly elongated the transverse sheets of cavities could not well have retained their original parallelism, and in such gneisses the arrangement of the cavities may be ascribed to the period of metamorphism.

Fluidal cavities in small dikes or veins.—In a veinlet of quartz and feldspar at the Calder & Carnie quarry at Westerly, R. I., the quartz particles are crowded with cavities in sheets parallel to the side of the vein and also in line with streaks of kaolinization in the feldspars. A smoky quartz vein averaging 0.35 inch thick, of pegmatitic origin, in the A. Milne quarry at Barre, Vt., shows many roughly parallel diagonal fractures. In thin section it has a largely feldspathic border, 0.2 inch thick, which is partly micacized, and inside of it the quartz is in places granulated. Discontinuous sheets of cavities with vacuoles extend both in the direction of the vein and at right angles to it, and some cracks with granular quartz zigzag along these directions. In places the cavities are abundant but without apparent arrangement. A section of a little pegmatite dike cutting the schist that overlies the granite at the Bailey quarry in Barre, Vt., shows sheets of cavities and rift cracks transverse to the dike and the foliation of the schist. Small pegmatite dikes proceeding from the granite surface into the overlying mica slate at the Anderson quarry in the same township also show two transverse sets of sheets of cavities, one parallel to the dike and another across it.

Are some fluidal cavities secondary?—Van Hise [50] points out that in a certain quartzite of the Black Hills rows of minute gas-filled or liquid-filled inclusions running in parallel lines across the entire section, transverse to the longer axes of the quartz grains, with rows of black ferrite and secondary quartz similarly oriented, are of secondary origin. He regards them as probably due to the fracture of the grains by mechanical action and the introduction of liquid along the cracks, with the later deposition of secondary quartz, which has retained the liquid as inclusions.

Some vitreous Cambrian quartzite collected by the writer near Fort Ann, Washington County, N. Y., in 1899, shows in thin section enlargement of the original quartz grains by secondary interstitial quartz and also sheets of liquid inclusions intersecting one another at various angles within the quartz grains. As these sheets of cavities stop abruptly at the edge of the original quartz grains, and the courses of the sheets in different grains are not parallel but quite discordant with one another, it is evident that these liquid inclusions antedate the

[50] Van Hise, C. R., Pre-Cambrian of the Black Hills: Geol. Soc. America Bull., vol. 1, pp. 216–218, fig. 4, 1890; A treatise on metamorphism: U. S. Geol. Survey Mon. 47, p. 620, 1904.

metamorphism which produced the quartzite.[51] A thin section of a calcareous sandstone from the same vicinity shows similar sheets of cavities in its quartz grains, but their directions are such that they can have had no relation whatever to the bedding planes of the sandstone or to any secondary fractures in it, but their origin must date back to the granite or gneiss from which they came.

The inference to be drawn from the quartzites of the Black Hills and Fort Ann is that lines or sheets of fluidal cavities within the quartz grains of a quartzite may be secondary or primary—that is, they may have originated in the process of the formation of the quartzite or they may have been associated with that of the parent granite or gneiss itself. The thin sections themselves will indicate in most cases the mode of origin.

C. W. Cross[52] in 1881 described a gneissoid plagioclase-pyroxene rock from Roquedas, near Vannes, in Brittany, which bears on the origin of fluidal cavities. A summary follows:

> The outcrop is between tide levels, and its feldspars are therefore much weathered, the orthoclase passing into muscovite and the plagioclase into wollastonite. The weathered feldspar shows rows of fluidal cavities with vacuoles, and some of the cavities have negative crystal boundaries. These rows of cavities, however, form the continuation of acicular crystals of wollastonite, which occur at the beginning of the zone of weathering and radiate into the fresh feldspar. Delicate lines corresponding to the sides of the crystal and extending beyond them into the feldspar connect the rows of cavities. These rows disappear in the more altered parts of the feldspar. The fluidal cavities are regarded as clearly secondary and as precursors of the wollastonite. Where the feldspars are much altered similar rows of fluidal cavities begin to extend into the pyroxene from the wollastonite crystals. The same rock has streaks crossing differently oriented quartz particles. One such streak crosses 14 particles of quartz, 5 of plagioclase, 5 of titanite, and 4 of pyroxene—that is, 28 different crystal individuals. In a titanite the streak is represented only by a crack, but as it reaches the quartz or the plagioclase it contains fluidal cavities.

These rows of fluidal cavities associated with the marine weathering of a gneiss and the alteration of its plagioclase into wollastonite are of very different origin from the fluidal cavities common in quartz crystals. They also differ from the sheets of cavities in the fresh parts of granite, which do not extend into the feldspars. Only one of the many sections of New England granites examined by the writer showed cavities bounded by crystal faces. That one was a section of the hornblende-augite granite of Mount Ascutney, in Vermont (p. 162.)

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[51] See also Merrill, G. P., Fluidal cavities in quartz grains of sandstones: Science, vol. 1, p. 221, 1883. He calls attention to the same sandstone or quartzite near Fort Ann, and to the rapid movement of the vacuoles within the fluidal cavities.

[52] Cross, C. W., Studien über bretonische Gesteine: Min. pet. Mitt., N. F., vol. 3, pp. 373–376, pl. 7, figs. 1, 2, 1881.

E. S. Bastin,[53] in studying the pegmatites of Maine, found that some of the sheets of fluidal cavities in the quartz of pegmatite pass without deflection from an area of unstrained quartz into a strained and a recrystallized zone of it, as clearly shown in his photomicrograph. The writer finds in his granite sections one from the Marr & Gordon quarry in Barre, Vt., in which sheets of fluidal cavities cross strained quartz without deflection, as they do also in the granite gneiss from Peru, Vt., described on page 21. But such examples do not prove that the cavities were formed or arranged after the straining, for changes in the orientation of the quartz molecules and even their recrystallization in place would not necessarily alter the courses of the sheets of cavities, nor is the passage of sheets of cavities without deflection from one crystal of quartz to another evidence that the cavities were formed or arranged after the crystallization of the quartz. The arrangement of the cavities and the crystallization of the quartz, the first governed by crustal strains and the second by crystalline cohesion, may have been synchronous processes.

No such rows of fluidal cavities as Rosenbusch[54] describes as connected by fine cylindrical canals and as occurring especially in granites containing quartz with crush borders have been detected in the New England granites studied by the writer. Rosenbusch regards these as possibly of secondary origin or else caused by crustal compression.

SUMMARY ON RIFT AND GRAIN.

1. Rift and grain structure consists of minute cracks from 0.09 to 1.3 millimeters apart crossing the quartz particles and extending into the feldspars. These cracks produce a rough fissility in two rectangular directions, that of the rift being more pronounced.

2. One of these sets of fractures is always horizontal, or nearly so, and the other is vertical, or nearly so.

3. Both sets are independent of flow structure.

4. Both sets are independent of sheet structure, intersecting granite domes, except where one of them chances to coincide with the sheets in part of their course.

5. Rift is usually parallel to the mica plates and in many porphyritic granites to the longer axes of the phenocrysts (isolated large feldspars).

6. Rift and grain are not pronounced in all granites. Either or both may be very feeble or both may be absent.

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[53] Origin of the pegmatites of Maine: Jour. Geology, vol. 18, p. 308, 1910; Geology of the pegmatites and associated rocks of Maine, including feldspar, quartz, mica, and gem deposits: U. S. Geol. Survey Bull. 445, pp. 19–21, pl. 6, fig. 4, 1911.

[54] Mikroskopische Physiographie, 4th ed., vol. 2, pp. 41, 42, 1907.

7. Rift and grain fractures are about parallel to or coincide with sheets of fluidal cavities in the quartz particles. In some places the fracture extends from the end of the sheet into the quartz only; in others it continues into the feldspars. These cavities measure from less than 0.0028 to 0.03 millimeter in diameter. The sheets cross one another at right angles, but those in the grain direction are less abundant.

8. These sheets of fluidal cavities with vacuoles pass without interruption or deflection from one crystal particle of quartz to the adjacent one or from an area of unstrained quartz into an area of strained and recrystallized quartz.

9. Some sheets of cavities are diagonal to rift and grain directions, and some cavities appear to be without arrangement.

10. The sheets of cavities in granitic quartz stop abruptly at its contact with the quartz of any inclusion or rock intruded by the granite. Thus at an inclusion of schist on Blue Mountain, in Ryegate, Vt., also at the schist mass in the Marr & Gordon quarry, in Barre, Vt., where, although the two rocks are firmly welded together and the quartz of the schist has sheets of cavities, those of the quartz of the granite stop at the quartz of the schist.

11. Rift and sheets of fluidal cavities occur also in granite gneiss, usually parallel to its foliation but in places at right angles to it.

12. Small quartz veins, presumably of pegmatitic origin, and small granitic and pegmatitic dikes cutting granite or schist also have sheets of cavities and rift cracks. Some of these are parallel to the sides of the dike, and some dikes have a second set at right angles to the first.

13. Secondary minerals (sericite, riebeckite, limonite) form within the rift or grain cracks.

14. Rift and grain are affected by temperature. Granite splits more readily along the rift in winter.

15. Rift appears to be slightly deflected by gravity. A detached block of granite splits at one angle from the top but at another from the side.

16. Rift is also affected by present compressive crustal strain, an undetached block having a horizontal rift when split from one point of the compass but acquiring a slightly inclined rift when split from a point of the compass removed 90° or 180° from the first point. (Data obtained from experienced granite workmen at Concord, N. H., and Quincy, Mass.)

The facts adduced support the following interpretation of the order of events in the formation of rift and grain structure:

(*a*) During the consolidation of granite, when the quartz, the last constituent to consolidate, was crystallizing, the fluidal cavities were formed and, in obedience to crustal strain, were largely alined, some

in approximately horizontal sheets and others in vertical sheets. Under the same strain the mica plates in most granites and the large feldspars in many porphyritic granites became alined with their long axes in the rift direction.[55]

(*b*) After complete consolidation, as crustal strain continued, rift and grain cracks ensued, following more or less continuously the planes of diminished cohesion afforded by the sheets of cavities; and these fractures were extended from the quartz into the feldspars.

(*c*) Under later metamorphism and deep-seated weathering secondary minerals were deposited in the rift and grain cracks, and kaolinization took place along the feldspar fissures.

(*d*) Wherever a granite with fluidal cavities passed under metamorphism into a gneiss and the quartz was simply recrystallized in place, the sheets of cavities persisted, but where under more intense metamorphism the minerals were rearranged as well as recrystallized the fluidal cavities in the quartz under the new compression became realined, some of the sheets of cavities and the later ensuing cracks being parallel to the gneiss foliation and others running across it.

Rift and grain structure has been the chief economic factor in granite quarrying from the time of the ancient Egyptian quarrymen to the present. Although the rift cracks do not greatly weaken the stone they diminish its compressive strength. The average difference (loss) of compressive strength shown by two tests made by the United States Ordnance Department on granite from Mount Waldo, Maine, and Concord, N. H., one with the pressure applied at right angles to the rift and the other in the same direction as the rift, was 11.8 per cent.

SHEET STRUCTURE.

The division of granite into "sheets" or "beds" by jointlike fractures which are variously curved or nearly horizontal, being generally parallel with the granite surface, attracted the attention of geologists long ago. In 1797 De Dolomieu and shortly before that De Saussure[56] described granite sheet structure.

In 1803 Pötsch[57] published a paper on the subject. In 1841 Edward Hitchcock[58] described what he termed the "pseudostratification of granite," near Worcester and Fitchburg, Mass., as a concentric, onionlike structure generally conforming to the rock surface.

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[55] The orientation by crustal compression of mica scales, feldspar crystals, and fluidal cavities in granite during its consolidation is somewhat analogous to the process in one of the early experiments made to illustrate slaty cleavage, where unarranged metallic scales in a mass of plastic clay became oriented with reference to the pressure brought to bear upon the mass.

[56] Jour. des mines, vol. 7, No. 43, p. 426, 1797.

[57] Bemerkungen und Beobachtungen über das Vorkommen des Granits in geschichtete Lagen, p. 140, 1803.

[58] Final report on the geology of Massachusetts, p. 683, 1841.

In 1860 C. F. Naumann[59] dealt with the subject.

In 1863 F. von Adrian[60] described the structure in Bohemia and regarded it as the result of cooling.

In 1879 Reyer[61] described it as found in another part of Bohemia; and in 1894 Zirkel[62] also treated the subject.

Although this is the most striking feature in every granite quarry and next to the rift and grain is of the greatest importance to the granite industry, there is much diversity of opinion as to its cause. Whitney[63] writes:

> The curves are arranged strictly with reference to the surface of the masses of rock, showing clearly that they must have been produced by the contraction of the material while cooling or solidifying and also giving very strongly the impression that in many places we see something of the original shape of the surface as it was when the granitic mass assumed its present position.

Shaler, a few years later,[64] attributed the sheet structure to expansion due to solar heat.

C. H. Hitchcock[65] notices in New Hampshire granite "numerous joints, the planes of which correspond very nearly with the slope of the hill," but does not undertake to explain them.

Vogt[66] states that the sheets in granites of southeastern Norway measure from 6 inches to 6 feet in thickness and dip from 8° to 33° on the sides of the mountains, toward the valleys, but that they are horizontal on top and approximately parallel to the surface. He shows that they are of preglacial origin, attributes them to the same cause that is postulated by Whitney for those in California, and regards them as parallel to the original surface of the granite masses.

Harris[67] referring to the English granite quarries, writes: "In every quarry we visited we found that the direction of the 'beds' approximately corresponded with the outline of the hill on which it was situated." He offers no explanation of the phenomenon, however.

J. J. Crawford[68] describes the sheet structure at granite quarries in Madera and Tulare counties, Calif., as consisting of "concentric

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[59] Lehrbuch der Geognosie, 2d ed., vol. 2, p. 191, Leipzig, 1860.

[60] K.-k. geol. Reichsanstalt Jahrb., vol. 13, pp. 155–182, 1863.

[61] Idem, vol. 29, p. 405, 1879.

[62] Lehrbuch der Petrographie, 2d ed., vol. 2, p. 52, 1894.

[63] Whitney, J. D., Geology of California, vol. 1, Geology, p. 372; also pp. 227, 417 figs. 49–54, 1865.

[64] Shaler, N. S., Notes on the concentric structure of granitic rocks: Boston Soc. Nat. Hist. Proc., vol. 12, pp. 289–293, 1869.

[65] Geology of New Hampshire, vol. 2, pp. 511–512, plate opposite p. 158, showing sheet structure at the "Flume," 1877.

[66] Vogt, J. H. L., Sheets of granite and syenite in their relation to the present surface: Geol. Fören. Förh., No. 56, vol. 4, No. 14, 1879; also Nogle, Bemaerkninger om Granit: Christiania Videnskabsselsk. Förh., No. 9, 1881.

[67] Harris, G. F., Granites and our granite industries, London, 1888.

[68] California State Mineralogist Twelfth Rept., pp. 384–387, 3 plates, 1894.

layers conforming in a general way to the contour of the hills," but suggests no cause for them.

Herrmann,[69] who made a special economic study of the granites of Saxony, writes:

> Upon closer inspection it appears that the granite sheets are elongated lenses overlying one another, of which the upper one, as a rule, has its bulging part lying in the depression formed by the two underlying lenses where they come together.

Branner[70] describes the exfoliation of the granitoid gneisses in Brazil, which he attributes only in part to changes of temperature. He calls attention to the fact that the linear expansion of a mass of gneiss 300 feet long at a depth of 15 feet from the surface under a surface temperature of 103° F. would amount to only 0.072 inch; and he quotes the results of Forbes, Quetelet, and others to show that the annual change of temperature can penetrate rock only to a depth of 40 feet in temperate regions and still less in the Tropics.

Merrill[71] describes Stone Mountain, in Georgia, as a boss of granite 2 miles long by 1½ miles wide and 650 feet high, which owes its form wholly to exfoliation parallel to preexisting lines of weakness. The mass appears to be made up of imbricated sheets of granite which he regards as the result of torsional strains. The bosslike form is incidental and consequent. Intermittent expansion and contraction from changes of temperature have so affected the sheets that bound the mass at the sides that they have found relief in expansion in an upward direction. These ruptured sheets are rarely more than 10 inches thick, but are 10 or 20 feet in diameter.[72]

Herrmann[73] sums up his conclusions on the subject substantially as follows: The so-called sheets are thin near the rock surface, generally only a few centimeters thick, but become gradually thicker with increasing depth. This downward increase in the thickness of the sheets is generally more rapid where the texture of the stone is coarser. The course of the sheets is not, as Vogt claims, parallel to the original surface of the consolidating rock. It is not governed by internal strains. The attitude of the sheets corresponds to the form of the present rock surface. The sheet structure is to be looked upon as the effect of the beginning and progress of weathering from the sur-

[69] Herrmann, O., Technische Verwerthung der Lausitzer Granite: Zeitschr. prakt. Geologie, 1895, p. 435.

[70] Branner, J. C., Decomposition of rocks in Brazil: Geol. Soc. America Bull., vol. 7, pp. 269–277, 285–292, 1896.

[71] Merrill, G. P., Rocks, rock weathering, and soils, 2d ed., p. 231, 1906.

[72] For description and representations of Stone Mountain see Merrill, G. P., op. cit., pl. 1; Purington, C. W., Geological and topographical features of the region about Atlanta, Ga.: Am. Geologist, vol. 14, pp. 105–108, pl. 4, 1894; also Watson, T. L., Georgia Geol. Survey Bull. 9–A, p. 113, pls. 1–8, 1902. See also description of another granite dome—Stone Mountain, in North Carolina—by Watson and Laney, in North Carolina Geol. Survey Bull. No. 2, pl. 25, 1906.

[73] Herrmann, O., Steinbruchindustrie und Steinbruchgeologie, pp. 109–111, 1899.

face inward. These weathering cracks are determined by the form of the rock surface instead of that being determined by them.

Turner[74] calls attention to the sheet structure and exfoliation of Fairview dome, in the Yosemite.

Gilbert[75] shows that sheet structure occurs in synclinal as well as in anticlinal attitude—in other words, is parallel to hollows as well as to hills—which he considers unfavorable to the theory that it is an original structure. He suggests that sheet structure may possibly be due to expansive stress consequent upon relief from compressive stress brought about by the removal of the mass into which the granite was intruded. Subordinately he notes that in the Sierra, at least, the dome structure and the parallel joint structure do not occur in the same place and that the former has resisted general erosion more successfully than the latter.

G. F. Becker, in a conversation with the writer, stated that he had found the granites and gneisses at the bottom of the Colorado Canyon both vertically and horizontally jointed. If these are true granites and are still in contact with the rocks into which they were intruded and show genuine sheet structure the phenomenon would conclusively prove that such structure may occur independently of solar heat and load.

S. F. Emmons similarly stated that in the Mosquito (Park) Range, in Colorado, the pre-Cambrian granite and schist are cut by horizontal joints to a depth of 50 feet below their contact with the overlying Cambrian, and that the joints diminish in number downward. The original load upon the granite here consisted of at least 10,000 feet of Paleozoic rocks and between 5,000 and 6,000 feet of Cretaceous rocks. As the granite, however, was not intruded into Cambrian sediments it must have been exposed to atmospheric erosion before they were deposited. These horizontal joints may therefore have been related to solar temperature.

G. K. Gilbert studied the granite domes of Georgia and attributed their sheet structure to compressive strains. He found that the granite in these domes[76] is not naturally divided into plates, but that the outer parts of the granite—the parts nearest the surface—are in a condition of compressive strain, which results in slow exfoliation and which enables quarrymen, by means of carefully regulated blasts, to develop joints that run approximately parallel to the surface, so that the granite is detached in sheets. As these

[74] Turner, H. W., The Pleistocene geology of the south-central Sierra Nevada, with especial reference to the origin of the Yosemite Valley: California Acad. Sci. Proc., 3d ser., Geology, vol. 1, No. 9, Formation of domes, pp. 312–314, pl. 37, 1900.

[75] Gilbert, G. K., Domes and dome structure of the high Sierras: Geol. Soc. America Bull., vol. 15, pp. 29–36, pl. 3, 1904.

[76] Letters to writer dated May 4 and June 11, 1906.

sheets are divided into blocks in the process of quarrying, the blocks expand horizontally as they are released from the general mass. In these granitic domes parting planes also develop naturally within a few inches of the surface, and the expansive force is there so great as to induce conspicuous buckling in the thin sheets thus formed. This buckling is illustrated in Plate XV, *A*, from a photograph taken by Gilbert. The jar of blasting precipitates this sheeting action, so that several of the domes at which quarrying is in progress show long lines of freshly formed disrupted arches. Gilbert found that the horizontal elongation, or rather the elongation approximately coincident with the contour of the dome surface, amounted, by one measurement, to 0.75 inch in a length of 40 feet.

The effects of compressive strain on granite were observed by the writer in 1907 at a quarry at the west foot of Black Mountain, a domelike mass in West Dummerston, near Brattleboro, Vt., and are illustrated in Plate VI, *A*. New thin sheets have thus been formed and one of the sheet fractures opened 3½ inches.

The owner of a large granite quarry in Westford, Mass. (p. 310) finds that the sheets are under a compressive strain which relieves itself by an expansion amounting to an inch in 100 feet, or 0.0083.

The artificial production of sheets in granite, as practiced at Bangalore, in southern India, shows similar phenomena. It is described by H. Warth[77] in substance as follows: At the surface there is a horizontal sheet of rather weathered rock 4 feet thick; below this lies a sheet of fresh rock 3 feet thick, but below this lies fresh rock without split. These sheets "are probably due to the variations of temperature, daily and seasonal." By means of wood fires plates 60 by 40 feet by 6 inches in thickness are detached in one piece. A line of fire 7 feet long is gradually elongated and moved over the granite. The effect of the fire is tested by hammering the granite in front of it, and then the fire is moved forward. The maximum length of the arc of fire is 25 feet. The burning lasts eight hours; the line of fire is advanced 6 feet an hour. The area passed over by the line of fire is 460 square feet. The amount of wood used is 15 hundredweight. The average thickness of stone is 5 inches, and its specific gravity is 2.62. These data show that 1 pound of wood suffices to quarry 30 pounds of stone. Some plates are taken out in inclined position. The action of fire is independent of the original surface of rock, also of the direction of lamination (the granite is gneissose) and of veins. The uniformity in the thickness of the sheets is attributed to the regulating influence of preexisting cracks.

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[77] The quarrying of granite in India: Nature, vol. 51, p. 272, 1895.

Van Hise[78] is inclined to attribute sheet structure to solar temperature.

Oxaal[79] connects sheet and rift structure. "In the cooling of the granite mass a strain or tension is caused which is relieved naturally in the formation of cracks in the line of least resistance, namely, parallel with the rift."

Before these theories are discussed sheet structures as exposed at a few of the larger quarries in Maine will be described.

Dome form and sheet structure are most finely exhibited at Crotch Island, near Stonington, and at Mosquito Mountain, near Frankfort. Plate X, *B*, shows the structure in the southern half of Crotch Island, at Thurlow Head. The dome is oblate, measuring about 1,500 feet from north to south and 140 feet in height.

Plate XI, *A*, from a photograph of the Ryan-Parker quarry, at the southern edge of the dome, shows that the sheets rapidly increase in thickness downward—from 1 to 25 feet in a depth of 75 feet—and that they dip 20°–25° S. At the next quarry north, the Goss quarry (see p. 226), the excavation has exposed the center of the dome mass. Here the sheets dip both north and south, measure from 1 to 30 feet in thickness, and extend to a depth of fully 140 feet from the surface. At both of these quarries the rift is vertical and thus intersects the dome sheet structure.

Mosquito Mountain, 2 miles south of Frankfort, in Waldo County, is an oval granite dome 545 feet high, with a north-south axis about 1 mile long and measuring about half a mile across. It has a steep east face, the sheet structure of which is shown in Plate XI, *B*. On the top of this mountain, where the quarry is situated, the sheets dip gently north, west, and east, tapering out on the sides, and are 6 to 15 feet thick. The dome sheet structure is intersected by horizontal rift and vertical grain.

At the Mount Waldo quarry, 1¼ miles north-northwest of the top of Mosquito Mountain, the sheets dip 10° and are 8 inches to 8 feet thick, and the excavation averages about 20 feet in depth, about 300 feet from north to south, and 400 feet from east to west. The granite here is evidently under compressive strain, for the progress of quarrying resulted in a vertical fissure, running north-northwest by south-southeast for the entire width of the quarry and across the rift, which is horizontal. The formation of the fissure was accompanied by a dull explosive noise. At several other quarries in the State foremen report a partial closing of vertical drill holes by expansion or compressive strain of the rock. (See pp. 236, 251.)

[78] Van Hise, C. R., A treatise on metamorphism: U. S. Geol. Survey Mon. 47, pp. 434–439, 1904.

[79] Oxaal, John, Norsk Granit: Norges geol. Undersökelse No. 76, p. 211, 1916.

At the White quarry, in Bluehill, the granite breaks with explosive sound when split in large sheets along a vertical rift that extends N. 50° W. The gradual increase in the thickness of sheets downward is well shown at the Stinchfield quarry, near Hallowell (Pl. XII, *B*). Their evenness and curvature are shown at the Sands quarry, at Vinalhaven (Pl. XIV, *A*). At the Hurricane Island quarry (Pl. XII, *A*) the excavation is 105 feet deep. The upper sheets measure from 3 to 20 feet in thickness, but the lowest sheet is fully 60 feet thick. A good cross-section of granite sheets is seen at the Crabtree & Havey quarry, in Sullivan, shown in Plate XIII, *B*, which brings out their lenticular form and arrangement. The tapering end of one lens lies between the thickest parts of two others. This accounts for the apparent irregularity in the thickness of the sheets in some longitudinal sections, notwithstanding their progressive thickening downward. (Compare Pl. XIII, *A*, taken at the same quarry, with Pl. XIII, *B*.)

Sheet structure as exposed in the other New England quarries is described on pages 297 and 320 and is illustrated in Plates XXV, *A*, and XXVII, *A*; its relation to overlying rocks is shown in Plates VIII, *A*, XVII, *A*, and XXXIV, *A*, and figures 14, 15, 17, 18, 93.

The observations as to sheet structure made at over 100 of these quarries are here summarized:

1. There is a general parallelism between the sheets and the rock surface, resulting in a wavelike joint structure and surface over large areas.

2. The sheets increase in thickness more or less gradually downward.

3. The sheets are generally lenses, though in some places their form is obscure. Their thick and thin parts alternate vertically with one another. The joints that separate these superposed lenses therefore undulate in such a way that only every other set is parallel.

4. On Crotch Island, Maine, the sheet structure extends to a depth of at least 140 feet from the surface, and at Quincy, Mass., to 250 feet.

5. Sheet structure, with rare exceptions, intersects the rift.

6. There are indications here and there that the granite is under compressive strain, which tends to form vertical fissures or to expand the sheets horizontally so as to fill up small artificial openings or to extend the sheet partings horizontally. (See pp. 153, 198, 236, 251.)

The observations made in Europe and in this country, taken in connection with the inferences geologists have drawn from them, indicate that sheet or "onion" structure in granite rocks is due to the following possible causes:

1. To expansion caused by solar heat after the exposure of the granite by erosion.

2. To contraction in the cooling of the granite while it was still under its load of beds, the sheets being therefore approximately parallel to the original contact surface of the intrusive.

3. To tensional strain in the cooling of the granite finding relief in the direction of the rift.

4. To expansive stress or tensile strain brought about by the diminution of the compressive stress in consequence of the removal of the overlying material.

5. To concentric weathering due to original texture or mineral composition. This action would be chiefly chemical and would be aided by vertical joints and by any superficial cracks due to expansion and contraction under changes of temperature.

6. To compressive strain akin to that which has operated in the folding of sedimentary beds.

7. To the cause named under 1 at the surface, but to the cause named under 6 lower down.

These propositions will be considered in the order given:

1. Solar heat may produce a certain amount of exfoliation in thin sheets at the surface, as is proved experimentally in the fire method of granite quarrying in India (p. 30), but as it penetrates only to a depth of 40 feet and as sheet structure is known to occur on Crotch Island, Maine, at a depth of 140 feet and at Quincy, Mass., at a depth of 175 feet, it is quite inadequate to account for sheets that are 20 to 30 feet thick and 100 to 175 feet below the surface. In Quincy at a depth of 175 feet the next sheet is over 50 feet thick.

2. In view of the load under which granite was probably formed [80] and the gradual rate at which, therefore, it probably cooled, which is also indicated by the general coarseness of its texture, it is improbable that the temperature at its contact surface and the temperature at depths 100 or 200 feet below could have so greatly differed as to bring about such a system of joints by contraction.

3. As the sheets in very many New England granite quarries and notably in the domes of Crotch Island and Mosquito Mountain, Maine, cross the rift the explanation that postulates relief from tensional strain in the direction of the rift will not answer. Wher-

[80] See p. 4. Sorby thought that this load could be estimated by calculating the contraction of the liquid in the cavities of the quartz. Sorby, H. C., On the microscopic structure of crystals, indicating the origin of minerals and rocks. Geol. Soc. London Quart. Jour., vol. 14, pp. 453 et seq., 1858. Ward, J. C., On the granitic, granitoid, and associated metamorphic rocks of the Lake district. Idem, vol. 31, pp. 568–602, 1875. Rosenbusch claims that the great variation in the relative dimensions (amount) of the liquid and the vacuoles in the cavities of granitic quartz shows conclusively that the vacuole was not due to the contraction of the liquid. Mikroskopische Physiographie der Mineralien und Gesteine, 4th ed., vol. 2, pp. 41, 42. For further discussion of this question see Chamberlin, R. T., op. cit., pp. 64–66. For drawings of these cavities and vacuoles see Judd, J. W., Volcanoes, figs. 8, 9, 1881; also Bastin, E. S., U. S. Geol. Survey Bull. 445, fig. 4, 1911.

ever the sheets are parallel to the rift it is a coincidence, not an effect. Sheets also occur in granite gneiss (see figs. 14, 15, 17, and Pls. VIII, *A*, XXXIV, *A*) and in places intersect its rift. The same sheets even traverse a granite and the overlying granite gneiss intruded by it. (See Pl. XXXIV, *A*, and fig. 17.) At the lower Sherwood quarry, on Crotch Island, Maine, sheet structure crosses the contact of a coarse and a very fine granite—that is, the direction of the flow structure—at 90° (see fig. 51) and a vertical rift at 75°. Its origin was therefore subsequent to consolidation and to rift and unrelated to flow and rift.

4. As Gilbert states, in suggesting the theory of fracture by relief of tensile strain through the erosion of overlying masses, we have no distinct knowledge of it. It is a possible explanation.

5. Careful inspection of the rock on both sides of the sheet joints fails to show any difference in texture or mineral composition. The sheet structure traverses both rift and flow structure, and it would be possible to procure specimens showing a sheet joint traversing a single crystal of feldspar. Whatever chemical action has taken place along the sheet joints is of secondary character. Acid waters may have gained access to the joint but have not caused it. (See matter under heading "Rusty stain ('sap')," p. 66.)

6. The condition of strain described by Merrill and Gilbert as existing in the granite domes of Georgia and by Niles and Emerson in the gneiss at Monson, Mass.,[81] and by the writer at West Dummerston, Vt. (p. 153 and Pl. VI, *A*), and occuring to a lesser extent in some Maine quarries (p. 236), shows that granite and gneiss are in places still under compressive strain. Another instance occurs at the quarry of the New England Granite Works, at Concord, N. H. (p. 198). The foreman at this quarry was in the habit of calling certain sheets marked by the absence of rusty stain "strain sheets," to distinguish them from the others. At one place a northwest-southeast compressive strain had actually extended the strain sheet about 5 feet and also caused a vertical fracture that extended over 15 feet diagonally from the north-south working face to a point on a vertical east-west channel 5 feet back of the face, closing up the channel to half its original width. Evidences of compressive strain were also noted at Quincy (p. 320) and Rockport, Mass. (p. 294), and at Westerly, R. I. (p. 406), and have been observed by the writer in some of the quarries at Barre and Woodbury, Vt. (pp. 128, 147). The practicability of developing sheet structure by the use of explosives and compressed air, as is done in some of the North Carolina granite

[81] Niles, W. H., Some interesting phenomena observed in quarrying: Boston Soc. Nat. Hist. Proc., vol. 14, pp. 80–87, 1872, vol. 16, pp. 41–43, 1874. Emerson, B. K., Geology of Old Hampshire County, Mass.: U. S. Geol. Survey Mon. 39, pp. 63–65, 1898.

quarries, shows that the rock is under a compressive strain there.[82] Recent effects of compressive strain have been noticed in the granite quarries of Quenast, in Belgium.[83]

All these observations bring this theory within the domain of inductive science. If sheet structure is due to compressive strain, it is due to such a strain as would produce a series of undulating fractures extending entirely across a granite mass several miles in diameter and to a depth, as far as observed, of 250 feet from the rock surface.

7. In view of the undoubted sheeting effect of expansion under solar heat within a short distance of the surface[84] and of the fact that some of the sheets near the surface measure but a few inches in thickness, it is quite possible that very thin surface sheets have originated in this way; but in view of what was stated under heading 6 it seems probable that compressive strain is the main factor in producing massive sheets. At the surface both causes may have cooperated. The progressive thickness of the sheets downward indicates that the operation of this strain is evidently also dependent upon distance either from the present surface or from a former surface or contact.

According to this view sheet structure may be said to exert a controlling influence upon surface forms, yet it seems quite possible that granite domes as conspicuous as Stone Mountain, in Georgia, and Fairview Dome, in California, notwithstanding all the exfoliation that has taken place on them or the erosion they may have suffered, may still retain some degree of parallelism between their present form and the original contour of the granitic intrusions of which they are parts. This may be true also of the granite hills of Mount Desert.

The probability being admitted that the general parallelism between the present surface and the sheet structure is the result of erosion that followed the sheeting, the question still remains, What has determined the form and location of the domes? These may possibly be referred to major arches (anticlines) in the folds of the stratified rocks that originally overlay the granite. The crustal movement that produced these folds may also have brought about the intrusion of the material that formed the domes beneath them.

Although the sheet structure and the rock surface are very generally parallel, they are not universally so.

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[82] Watson, T. L., and Laney, F. B., The building and ornamental stones of North Carolina: North Carolina Geol. Survey Bull. 2, pp. 157–160, 1906.

[83] Hankar-Urban, A., Note sur des mouvements spontanés des roches dans les carrières: Soc. belge géol., pal. hydrol. Bull., vol. 19, pp. 527–540, 1905; also two later papers in vols. 21, 1907, and 23, 1909.

[84] See reference to Walther's observation of the exfoliation of granite under solar heat in Egypt, on p. 71.

Sheet structure in granite so much resembles the structure of folded stratified rocks that underground water circulates in practically the same way along the fracture planes of one and the bedding planes of the other. The exudation of water along sheet joints on vertical rock faces is seen in many of the Maine quarries (Pl. XIV, *B*), and also in Massachusetts (Pl. XXVII, *A*) and Rhode Island (Pl. XXXIV, *A*).

DOUBLE-SHEET STRUCTURE.

Robeson Mountain, in Woodbury, Vt., is a narrow granite ridge, attaining an elevation of about 1,100 feet above Hardwick station and some 930 feet above Woodbury (Sabin) Pond. It is from 300 to 400 feet above the hollows on either side of it. Its axis trends from N. 80° E. to S. 70° W., describing a slight curve. Near its west-southwest end the Fletcher quarry cuts the ridge in a northeast-southwest direction, and in 1907 had reached a depth of 40 feet. The sheets exposed here are from 1 to 5 feet thick, horizontal at the top of the ridge but curving over on the southeast with a dip of 15° to 30°, as shown in Plate VI, *B*, and determining the slope of the ridge on that side. These sheets are, however, intersected by another set from 5 to 9 feet thick, dipping 5°–10° S. 70° W. in the direction of the axis of the ridge. In the Woodbury Granite Co.'s quarries, roughly about 1,750 feet N. 80° E. of the Fletcher quarry, the sheets at the top of the ridge turn, dipping to the northern horizon. Lower down on the southeast side of the ridge they are from 2 to 18 feet thick and dip 20° SSE., with an intersecting set which is horizontal and evidently corresponds to the second set of the Fletcher quarry.

At one of the Oak Hill granite quarries, 6 miles west of Lowell, in Westford, Mass. (p. 310), the sheets, 6 inches to 8 feet thick, dip 10° NE. but are intersected by secondary sheets, 10 to 20 feet thick, dipping 20° N. 47° E.

Out of the 425 granite quarries visited by the writer in New England, these are the only ones in which secondary sheet structure was observed.

The only explanation offered for this double-sheet structure is the existence at some time of a secondary compressive strain operating differently from that which produced the primary sheet structure and giving rise to a nearly horizontal set of joints or sheet partings. There is now a marked compressive strain in the Fletcher quarry, operating from northeast to southwest, parting the sheets and giving rise even in the upper part of the quarry to horizontal strain fractures. Its existence lends support to such an explanation.

JOINTS.

Herrmann[85] divides joints into two groups—joints formed by lateral compression, whose distances from one another are related to the coarseness of the rock texture, and joints due to expansion some of which are parted and filled with calcite, quartz, pegmatite, or volcanic rock. That many joints are due to compressive or torsional strain, and that every such strain resolves itself into two components, resulting in two sets of joints that intersect at an angle of about 90°, each forming an angle of about 45° with the direction of the strain, are facts now generally recognized. Crosby[86] has suggested that torsional strains may have been supplemented by vibratory strains in causing joints. Becker[87] shows that four or even more than four systems of joints may be due to a single force. He also shows that subsequent strain on a region thus jointed would tend to produce motion along the previously formed joints rather than a new system of jointing. It is conceivable that if a region had been jointed and afterward subjected to a tensile strain, some of its joints might be parted, and if they were very deep the openings might become filled with volcanic matter from below, or, if not, with matter from above, infiltrated from overlying rocks. That motion has occurred along some of the joints in the quarries is evident from the polished and striated surfaces of the joints as well as from the faulting of the sheets.

Joints are exceptionally as curved "as the side of a ship." (See Pl. XIV, *B*.)

Possibly related to such curved joints are what some New England quarrymen term "toe nails." These joints strike with the sheets but extend only from one sheet surface to the next and have a curve which sharply intersects that of the sheet structure. Such joints seem to be due to a strain different from that which produced the sheets. They may be due to an incipient secondary sheet structure. They were noted at Quincy, Mass., Westerly, R. I., and Milford, N. H.

The spacing of the joints varies considerably, ranging from 1 foot to 500 feet, but usually from 10 to 50 feet.

In some localities the jointing is very irregular. The granite is broken up into various polygons, which at the surface, where weathering has made inroads, resemble boulders. Quarries opened in such places are called boulder quarries. Another sort of irregularity in joints consists in their discontinuity or intermittence, their strike and dip for the short spaces in which they occur being uniform. Joint

[85] Herrmann, O., Steinbruchindustrie und Steinbruchgeologie, p. 103, 1899.

[86] Crosby, W. O., The origin of parallel and intersecting joints: Am. Geologist, vol. 12, pp. 368–375, 1893.

[87] Becker, G. F., Simultaneous joints: Washington Acad. Sci. Proc., vol. 7, pp. 267–275, pl. 13, 1905.

courses at the quarries referred to in this work are given under the quarry descriptions in Part II, and many of them are there shown in diagrams.

HEADINGS.

In some places joints occur within intervals so short as to break up the rock into useless blocks. For a space of 5 to 50 feet the joints may be from 6 inches to 3 feet apart. A group of close joints is called by quarrymen a "heading," possibly because, when practicable, such a mass is left as the head or wall of the quarry. (See Pls. XVI, *A*; XVII, *B*.) Headings afford ample ingress for surface water, and consequently the granite within a heading is generally badly stained, if not decomposed. This will be referred to more fully under the heading "Decomposition" (p. 70).

An interesting feature of both headings and joints shown in some of the deeper quarries at Quincy, Mass. (p. 320), is their vertical discontinuity. A heading occurring at the surface may disappear below, or a heading may abruptly appear a hundred feet below the surface and continue downward.

The hornblende granite of High Rock, in Wrentham, Mass. (Curry quarry, p. 314), besides the usual sheet and joint structure, has steep headings at irregular intervals in its upper part. These are only 5 to 10 feet deep and several feet wide, differing from ordinary headings in the closeness of their joints, which are only 1 to 2 inches apart.

Headings are not easily accounted for. They may be produced by vibratory strains recurring at intervals of time. If they are so caused, the character of the fractures in some headings indicates that the strains are very complex. (See under Concord, N. H., p. 196.)

FAULTS.

The polished and grooved faces ("slickensides") observed on many of the joints at the quarries show that faulting has occurred along them. The discontinuity of the sheets at some of the joints, causing, where the joints are slightly inclined, what quarrymen call "toeing in," may probably be attributed to faulting. This supposition assumes, of course, that the sheet structure was formed prior to the jointing. Faulting occurs also along sheets, displacing vertical flow structure, or vertical dikes. (See Pl. XVI, *B*.) It may occur along one of two intersecting dikes, displacing the other, as at the Deep Pit on Cape Ann, Mass. (See Pl. XXVII, *B*.)

SHEAR ZONES.

Zones along which numerous microscopic parallel meandering fractures have been made and shearing has occurred, giving rise to secondary minerals and plicating the lamellae of plagioclase, were

observed at one of the quarries at Fall River, Mass. (See p. 283.) This is incipient gneissic foliation.

"SHAKE" STRUCTURE.

In quarries where rift structure and sheet structure happen to coincide the granite in proximity to steep joints and near the surface acquires a marked foliation parallel to rift and sheets. This is known by quarrymen as "shake." It occurs at the top and bottom of sheets through a thickness of 6 inches and is coextensive with the rusty stain. Under the microscope it proves to consist of minute nearly parallel fissures of no great continuity, traversing the mineral grains and conspicuous in the quartz and mica. The spacing of the fissures ranges from 0.004 to 0.02 inch.

The structure is attributed to the action of frost upon the rift, surface water having reached sheets and rift through steep joints. It is uncertain whether the fine horizontal fissures at right angles to the gneiss foliation but parallel to the sheets, and spaced 0.5 to 6 inches, at the Sachem Head quarry, in Guilford, Conn. (p. 384), are also to be so explained or constitute a miniature sheet structure.

SUBJOINTS.

Careful inspection shows that the joint structure in granites does not everywhere consist of a simple fracture but is at many places complex. Minute fractures branch off from the joint at an acute or right angle and penetrate the rock a few inches, or the rock for a few inches on either side of the joint is traversed by microscopic fissures that are roughly parallel to it. All such structural features may properly be called subjoints.

The following observations were made in the Maine granites and quarries:

A thin section of North Jay granite across a joint face shows two diverging subjoints that form an acute angle with each other and with the main joint and are filled with limonite and sericite (?). Single subjoints are, however, rarely found, five or six fine parallel fissures generally occurring together. In one of the quarries at Franklin (quarry of W. B. Blaisdell & Co., p. 220), the subjoints are parallel to the main joint and steeply inclined, and as both main and subjoints are filled with calcium carbonate the granite near the joint weathers out vertically in small slablike pieces from half an inch to 2 inches thick. As these usually contain one or more subjoints filled with calcite or aragonite they consist of alternating bands of calcium carbonate and granite. Under the microscope one of these subjoints, measuring 0.74 millimeters across, is seen to be filled with long slivers of quartz and feldspar and scales of biotite, forming a breccia. Another, 0.07 millimeter wide, is filled with secondary

quartz. At the T. M. Blaisdell qarry in East Franklin, Hancock County (p. 219), a northeast-southwest vertical joint has on one side numerous subjoints that meander off at right angles to it and traverse a cubical mass whose sides measure 10 to 15 feet. At the Shattuck Mountain quarry, in Calais (p. 266), a joint striking N. 25° E. has subjoints striking N. 40° E., N. 60° E., and N. 50° W.

Woodworth[88] has studied analogous and related structures in various rocks and described them as "joint fringe" and "feather fractures."

The term subjoint is here extended to include also series of minor parallel joints traversing quartz veins.

Such jointed veins occur in several quarries at Quincy, Mass., on the North Commons. They are made conspicuous by a zone of light discoloration in the granite on either side of the vein. At the Field & Wild quarry (see p. 326) these veins recur at intervals of 2 to 25 feet, with a north and northwest strike. They are crossed every inch or two by subjoints about 1 foot long, which strike about N. 15° W. and dip east like the chief joints of that quarry. At the Galvin quarry (see p. 325) similar quartz veins, striking N. 25° W., are crossed by vertical subjoints an inch apart and a foot long, with a northerly strike like that of the major joints. Workmen report that the granite near such veins is harder than elsewhere.

These subjoints may be accounted for by the greater rigidity and vitreousness of the veins and the adjacent granite, thus causing them to fracture more readily than the surrounding rock under the joint-forming movements. Although parallel to the major joints, such subjoints may have been formed at a different time.

CONTEMPORARY FRACTURES.

The geologic structural features termed contemporary fractures, formed by processes that are still going on, have been described under the subject of sheet structure on pages 29–30 and are illustrated in Pls. VI, *A*, and XV, *A*. The effect of compressive strain has also been noted at the Tayntor quarry, Hallowell, Maine (p. 236), the Hooper & Havey quarry, North Sullivan, Maine (p. 231), also at these quarries in Vermont: Woodbury quarry, Bethel, strain east to west; Boutwell quarry, Barre, strain north to south; Bruce quarry, Barre, strain north to south; Wells-Lamson quarry, Barre, strain north to south; Canton quarry, Barre, strain east to west; Fletcher quarry, Woodbury, strain northeast to southwest; Benzie quarry, Groton, strain general; Tupper quarry, Blue Mountain, Ryegate, strain east to west; Lyons quarry, Black Mountain, Dummerston, strain N. 10° E. to S. 10° W.

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[88] Woodworth, J. B., On the fracture system of joints, with remarks on certain great fractures: Boston Soc. Nat. Hist. Proc., vol. 27, pp. 169–173, pls. 1, 2, 1896.

The usual effect of such strains is the closing of channels and the crushing of "cores" (rock intervals) between vertical drill holes.

MODIFICATIONS OF GRANITE.

Under the above heading are grouped all those variations from typical granite that are due to injection, segregation, inclusion, steam cavities, compression, infiltration, and decomposition.

DIKES.

Dikes in granite are fissures filled from below by the injection of matter in a heated and more or less plastic to fluid condition. The injected material or dike rock may be acidic or basic—that is, it may be very siliceous, like granite, or it may contain more of the basic elements, like basalt.

ACIDIC DIKES.

The acidic dikes in the quarries are of three kinds—fine or medium grained granite; extremely fine grained aplite, and very coarse grained pegmatite. The courses of these dikes at each quarry are given in the diagrams or descriptions in Part II. In thickness they range from a fraction of an inch to over 20 feet but usually from 2 inches to 2 feet.

Granite.—The following observations were made in the Maine quarries: At the Settlement quarry, near Stonington (see p. 229), the coarse granite is traversed by a dike, 4 to 12 inches thick, of light pinkish-gray granite, in which the feldspars attain a size of 0.1 inch (2.5 millimeters). This rock consists of a pinkish potash feldspar (microcline), a white soda-lime feldspar (oligoclase-andesine), smoky quartz, and black mica (biotite). At the Mosquito Mountain quarry (p. 258), near Frankfort, there is a 10-foot dike of medium-grained gray granite (quartz monzonite), with feldspars up to 0.3 inch. The potash feldspar (microcline) is about equal in amount to the soda-lime feldspar (oligoclase), the quartz is smoky, and the mica is black. At the Mount Waldo quarry (p. 259) there is a dike 200 feet wide of fine biotite granite, with coarse biotite granite on both sides of it. The feldspars of this dike measure up to 0.15 inch, but range ordinarily from 0.36 to 1.45 millimeters. The fine-grained biotite-muscovite granites quarried at the Sherwood quarry, on Crotch Island (specimen 25, a, described on p. 227), at East Bluehill (specimen 39, a, p. 216), and at a small opening on Dodlin Hill, near Norridgewock (specimen 117, a, p. 257), all seem to belong to similar dikes that are not many feet thick. At an old quarry near Bluehill there is an 18-inch dike of fine-grained muscovite-biotite granite, in which the feldspars are much intergrown with quartz.

At Milford, Mass., the medium-coarse, even-grained, slightly gneissoid biotite granite is cut by a 4-foot dike of fine to medium grained porphyritic biotite granite. (See further p. 346.) The same granite at the West quarry (p. 348) is cut by dikes of fine quartz monzonite.

In Rhode Island the fine Westerly granites appear in dikelike masses from 50 to 150 feet thick, striking N. 75°–90° W. and dipping 30°–45°. At the Smith quarry they are underlain by a parallel mass of aplitic granite of similar character, carrying also inclusions of finely banded biotite gneiss. At the Klondike quarry the granite has a flow structure striking N. 10°–20° W., intersecting the course of the apparent dike. It is uncertain whether these are granite dikes or protuberances from a broad intrusive mass which have become exposed by the erosion of the thinner parts of the overlying gneiss.

The fine quartz monzonites of Connecticut, like those of Rhode Island, occur as dikes, or apparent dikes, in various gneisses. At the Waterford quarry there are two such parallel dikes with an intervening strip of gneiss. The relations are shown in figures 13 and 14. The thickness of the dikes measured at a right angle to their inclination ranges from 12 to 40 feet, but at the Millstone quarry the relations are not clear. The granite is exposed for a depth of 50 to 125 feet and a width of 50 to 300 feet, and is capped here and there by 25 feet of gneiss, but no underlying gneiss is yet exposed, although the abundance of inclusions at the bottom of the quarry may indicate its proximity. If the width of the granite at right angles to the flow, which appears to dip 35° SW. is taken as 200 feet, the thickness of the granite would be about 114 feet. It is possible that a part of this quarry overlies the vertical portion of a granite dike. (See pp. 396, 397.) At the Torrington Borough quarry (p. 379) a finely banded biotite granite gneiss associated with pyritiferous quartz-mica diorite gneiss is crossed by a network of dikes—the largest 6 inches thick—of bluish-gray quartz monzonite, which has acquired a gneissic texture.

In Dummerston, Vt., on the west side of Black River (Bailey prospect, p. 155), the granite is cut by a dike of fine granite, 30 feet wide, with a N. 10° W. course and dip of 50° W. It is of medium bluish-gray color and of very fine, even-grained texture, with feldspar and mica up to 0.05 inch. In thin section its particles range from 0.074 to 1.1 millimeters in diameter. It is a quartz monzonite of similar composition to that of West Dummerston. Its mica is chiefly biotite. Feldspar and quartz are intergrown and have crush borders.

Aplite.—Aplite differs from ordinary granite by the greater fineness of its texture and its scant content of mica. It is known by quarrymen as " salt horse " or " white horse."

Aplite dikes are supposed to have originated in the same deep-seated molten mass as the granite they traverse, but they represent a later stage of igneous activity. The fissures they fill were the result of various tensional strains or contractions, possibly consequent upon the cooling of the granite.

In color these dikes range from white, bluish or brownish gray to light pinkish gray, cream color, and dark reddish. The texture of some aplites is so fine that the mineral particles can not be distinguished with the unaided eye; that of others is so coarse that the feldspar and mica may be thus detected. Under the microscope the dimensions of the particles range from 0.05 to 0.75 millimeter, the average being about 0.16 millimeter for the finer ones and 0.50 millimeter for the coarser ones. Some aplites have a porphyritic texture.

Most aplites contain a slightly higher percentage of silica than granite. Five analyses of aplites from the far West made at the laboratory of the United States Geological Survey[89] show a range of silica from 74.21 to 76.03 per cent and an average of 75.18, which is near the maximum of silica for granites generally.

The minerals of aplite dikes are so firmly attached to the granite on either side that a split can be readily made across both granite and aplite. Under the microscope the minerals of the dike appear to be welded, so to speak, to those of the granite. In construction the blocks containing such dikes should not, therefore, necessarily be regarded as places of weakness, but in a quarry at Franklin, Hancock County, Maine, the granite is close jointed for a space of a foot on either side of an aplite dike, the joints being parallel to the dike.

Two typical aplites will be described in detail. One, from the Goss quarry on Moose Island, near Stonington, Maine, is from a dike 15 inches wide and over 200 feet long, consists largely of quartz, potash feldspar (microcline), and a soda-lime feldspar (oligoclase) in particles ranging from 0.047 to 0.141 millimeter in diameter, a few thinly disseminated particles of the same minerals measuring from 0.55 to 1.45 millimeters and a few scales of black mica measuring up to 0.47 millimeter. Another aplite, from the Sands quarry at Vinalhaven, Maine, consists mostly of quartz but contains some potash feldspar (orthoclase and microcline), still less soda-lime feldspar (oligoclase), and a few scales of black mica. The particles range from 0.047 to 0.3 millimeter in diameter.

Dikes of aplite were observed at the quarries in Roxbury, Benvenue, Bolton, Greenwich, and Sterling, Conn. Aplite is also associated with pegmatite at several other quarries.

At Roxbury some of the aplite is rose colored, and the larger dikes are 4 feet thick. Its particles are all under 0.1 inch and consist of oligoclase-andesine, smoky amethystine quartz, microcline, rare muscovite, and microscopic garnets. The feldspars have crush borders, the dikes having been exposed to the same pressure that made a gneiss of the inclosing granite. A white aplite from the same quarry has oligoclase-albite as its chief feldspar.

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[89] U. S. Geol. Survey Bull. 419, pp. 64, 86, 92, 148, 157, 1910.

At Benvenue the aplite is white to rose-colored, and the larger dikes are a foot thick. Its particles are all under 1 millimeter and consist of quartz, orthoclase and microcline, oligoclase, and rare biotite, with accessory pyrite, titanite, allanite.

At the Peterson quarry in Bolton an 18-inch bluish-gray aplite of slightly gneissic texture has quartz and feldspar particles from 0.11 to 0.33 millimeter, with some porphyritic particles from 0.54 to 0.84 millimeter, and consists of smoky quartz, bluish microcline and orthoclase, white plagioclase, and rare biotite.

The diorite gneiss of Greenwich is crossed by a network of small dikes of aplite of bluish-gray color, with particles under 0.76 and mostly under 0.57 millimeter and consisting of quartz with cavities in sheets, microcline and orthoclase, andesine, and probably oligoclase-andesine, rare and minute biotite, with accessory pyrite, apatite, titanite, zircon.

At the quarries near Oneco, in Sterling, the larger aplite dikes are a foot thick and the aplite is cream-colored, with particles ranging in diameter from 0.05 to 1.11 millimeters. It consists of clear colorless quartz with cavities, microroline and orthoclase, rare and minute biotite, and accessory ilmenite, garnet, and apatite. A small dike contains a central band of ilmenite.

At the Bodwell Granite Co.'s quarry (see p. 268), 2 miles east of Jonesboro, Washington County, Maine, the reddish granite is traversed by a 6-foot dike of rather coarse dark-reddish aplite, in which the higher power of the microscope shows that the source of the color lies in exceedingly minute dots of hematite. The aplite contains also muscovite, biotite, and accessory pyrite. This dike crosses the quarry in a N. 20° W. direction. A similar dike, having a like course, but only 4 feet wide, occurs at the east end of the quarry. A third dike, 3 to 6 inches wide, has a N. 77° E. course, and a fourth, of fine-grained material, 0.5 to 1 inch wide, crosses the others with a course N. 60° W. and can be traced for 200 to 300 feet. This is evidently of later date than the others.

The gneissoid biotite granite of the Savoie quarry, in Fall River, Mass. (p. 284), is crossed by two aplite dikes.

One (specimen D, XXX, 118, a), 10 feet wide, is of light pinkish-gray color and fine, even-grained texture. Its second feldspar is albite (soda feldspar), somewhat micacized and epidotized. Its biotite is chloritized. The other (specimen D, XXX, 118, b), up to 2 feet thick, is of dark brownish-gray color and semiporphyritic texture, its smaller particles generally arranged about the larger. Its second feldspar is also albite.

The biotite granite gneiss of the Blanchard quarry, in Uxbridge, Mass. (p. 353), has aplite dikes up to 3 feet thick.

The muscovite-biotite granite gneiss of the Merrill quarry, in Westford, Mass. (p. 310), has whitish aplite dikes with longitudinal bands of black tourmaline 0.2 inch wide.

A very unusual dike of aplite crosses the mica diorite of the Leavitt quarry, in Leominster, Mass. (p. 353). (See fig. 2.) It is of light-gray and bluish-gray color. Its broadest part consists of over 150 meandering parallel bands of these alternating shades

(specimens D, XXX, 110, b, c), many of them bordered with microscopic prisms of black tourmaline with their main axis across the band. The meanderings of these bands resemble the plications of a metamorphic stratified rock. The aplite contains here and there clear feldspars up to an inch long.

In thin section it resembles a quartz monzonite, its constituents, in descending order of abundance, being oligoclase-albite, quartz, microcline, and black tourmaline in minute prisms. The accessory minerals are apatite in needles and particles (abundant), pyrite, garnet, and flakes of muscovite (rare). The yellowish tinge of some of the bands is probably due to the oxidation of the pyrite. A few of the bands are pegmatite without tourmaline but with biotite, a little muscovite, and ilmenite (?) surrounded by leucoxene.

The banding of this aplite dike may be ascribed to a gradual enlargement of the fissure and the deposition of aplite on either side, as in banded mineral veins. The meandering or plication of the bands and the transverse orientation of the tourmaline prisms are possibly due to one cause. Other smaller dikes of aplite are parallel to this one, and some of aplite and of pegmatite intersect the main dike.

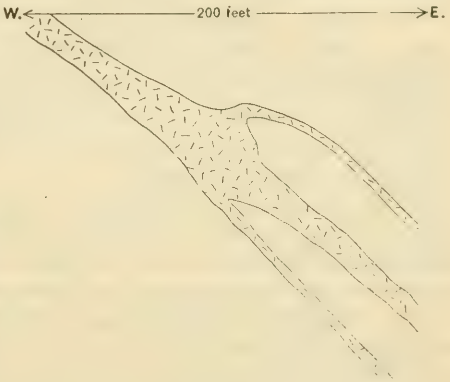

FIGURE 2.—Approximate horizontal section of banded aplite dike in diorite, Leavitt quarry, Leominster, Mass.

The considerable area of pyritiferous aplite quarried in Hingham, Mass. (p. 336), is of light, slightly greenish-gray color and scarcely developed sheet structure, but with many headings showing rusty faces from the limonitization of the pyrite.

This rock also resembles a quartz monzonite, with these constituents in descending order of abundance: Oligoclase-albite, quartz, microcline, and very little biotite mostly chloritized and associated with epidote. The accessory minerals are pyrite and magnetite. As the stone is extremely hard, its percentage of quartz must be high.

In Caledonia County, Vt. (Grout quarry, Kirby Township, p. 111), three aplite dikes strike N. 80° E. and are 6 feet 6 inches, 6 feet, and 1 foot thick.

This aplite (specimen D, XXIX, $\overline{76}$, b) is dark gray and of very fine porphyritic texture. But few particles can be distinguished; feldspar 0.1 inch, mica 0.05 inch. It effervesces slightly with muriatic acid test. In thin section the particles of groundmass range from 0.037 to 0.148 millimeter and consist, in descending order of abundance, of quartz, microcline (possibly also orthoclase), rare soda-lime feldspar, minute biotite scales, muscovite or bleached biotite, and secondary zoisite. The porphyritic particles and crystals are quartz, soda-lime feldspar, orthoclase, and biotite. One of the former feldspars has curved twinning planes, another is faulted across them and has much secondary quartz about it, all indicating motion after crystallization. Calcite is present.

Other aplite dikes in New England are referred to on pages 127, 167, 265, and 415.

Pegmatite.—Pegmatite lies at the other extreme. Its mineral constituents range generally from 6 inches to 1 foot or even several feet in diameter. It is reported that the crystals in some pegmatite dikes measure from 10 to 30 feet in length by 1 to 3 feet in width. The chief minerals in pegmatite dikes are the same as in granite, but they occur in different though varying proportions. With these minerals are commonly associated tourmaline, garnet, beryl, etc. Chemically these dikes generally contain more silica than the granite. Dikes of pegmatite are, as a rule, more irregular in width than those of aplite. They generally range in thickness from 1 inch to 10 feet.

The origin of pegmatite has been much discussed both in Europe and in this country.[90] Bastin in the bulletin cited states that the "distinguishing feature of pegmatites is not coarseness of grain but extreme irregularity of grain." Gregory[91] in showing the bearing of the phenomena in the granite quarries of Connecticut upon the origin of pegmatite states:

The contact between the pegmatites and the gneiss or other rock into which they have been intruded is clearly defined, showing no gradation between the pegmatite and the gneiss. In the feldspar quarries of Glastonbury, where the contact may be clearly traced, the gneiss immediately adjoining the pegmatite retains all the minute structures of foliation and differs in no way from the main body of granite gneiss. * * * The proportions of the chief minerals in pegmatites vary greatly. Some dikes or veins contain quartz, feldspar, and mica in about the same proportions as those found in normal granites. In other dikes feldspar and quartz make up practically the entire mass, and in some localities quartz alone constitutes probably 90 per cent of the entire rock.

Pegmatite may be regarded as a form of granitic intrusive that originated in parts of the igneous mass which were abundantly supplied with water vapor. Most masses of pegmatite were formed in a manner somewhat different from that in which ordinary granite was formed, and their composition varies with their distance from the granite mass. For instance, in the Collinsville granite gneiss area the pegmatities that are closely associated with the granite mass, such as those at Canton, are of essentially the same mineral content as the granite. The pegmatite farther away, which cuts the schist overlying the granite, is composed chiefly of quartz and feldspar, and that which lies still more distant is formed entirely of quartz.

Referring to the minerals occurring in pegmatite, Gregory states:

The pegmatite veins along Connecticut River have yielded sphalerite, gahnite, magnetite, chrysoberyl, bismutite, orthoclase (crystals), albite, oligoclase,

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[90] The principal American writings on the subject are those by Williams, G. H., The general relation of the granitic rocks in the middle Atlantic Piedmont Plateau: U. S. Geol. Survey Fifteenth Ann. Rept., pp. 675–684, 1895; Crosby, W. O., and Fuller, M. L., Origin of pegmatite: Tech. Quart., vol. 9, pp. 326–356, 1896; Am. Geologist, vol. 19, pp. 147–180, 1897; Van Hise, C. R., A treatise on metamorphism: U. S. Geol. Survey Mon. 47, pp. 720–728, 1904; Bastin, E. S., Geology of the pegmatites and associated rocks of Maine, including feldspar, quartz, mica, and gem deposits: U. S. Geol. Survey Bull. 445, 1911. An important European work on the subject is that of Brögger, W. C., Die Syenitpegmatit-gänge der südnorwegischen Augit- und Nephelinsyenite: Zeitschr. Kryst., vol. 16, 1890.

[91] Gfregory, H. E., U. S. Geol. Survey Bull. 484, pp. 18, 19, 1911.

beryl, iolite, garnet, epidote, tourmaline, muscovite (crystals), lepidolite, biotite, columbite, samarskite, monazite, triplite, torbernite, autunite, and uraninite. From a single pegmatite mass at Branchville twenty-seven minerals were collected. Single crystals taken from this mass weighed 100 to 200 pounds.

Bastin[92] names 20 minerals from the Maine pegmatites, exclusive of the quartz, feldspar, and mica of the dikes and the secondary minerals.

The writer's notes on the pegmatites of the Connecticut granite quarries follow:

Pegmatite in lenses or small dikes occurs at nearly all the quarries. There is a 20-foot dike with large gneiss inclusions at the Torrington Borough quarry (p. 375), and pegmatite occurs near or about such inclusions at the Millstone quarry (p. 396, fig. 90, b, d) and also at short intervals intersecting one another.

The permeation of the Stony Creek granite gneiss with pegmatite differentiates it from many granites and partly accounts for its very irregular texture. (See p. 378 and Pl. XXX, *A*.) The biotite granite of the MacCurdy quarry, at Lyme, is really a pegmatite occurring as dikes, 15 to 22 feet thick, cutting a mass of finely banded granite gneiss. (See p. 391.) At the Slater quarry, in Glastonbury (p. 369), a 12-inch pegmatite dike in fine porphyritic biotite granite gneiss contains muscovite crystals, the largest 5 inches across and 4 inches thick. At the Center Groton quarry the quartz monzonite on either side of a 4-foot pegmatite dike has been darkened. Dikes from 6 inches to 2 feet thick abound in the Holbrook quarry at Seymour. (See p. 385 and fig. 88.) At the Benvenue quarry, in Middletown, small pegmatite dikes are bordered with bands of feldspar and hornblende and the granite gneiss itself also contains hornblende.

Generally pegmatite dikes contain the same minerals as the granite they penetrate, but in larger particles. In the very fine granites such dikes afford a ready means of observing in the field the chief constituents of the granite they penetrate.

The pegmatite of Lyme village contains apatite, that of the Oneco quarry fluorite and epidote, that of Pawcatuck allanite, that of the Mascetti quarry, in East Litchfield, and the Potter quarry, in Ansonia, black tourmaline, and that of several other quarries garnets, all in small particles or crystals.

The pegmatite of the Collins quarry, in Danbury, owing to crustal motion, has all its quartz granulated like that of the gneissoid granite of Milford, Mass., and its feldspars bordered with crushed feldspar.

The courses of many of the pegmatite dikes and their relations to the structure of the granite in the New England quarries are shown in figures 4, 32, 33, 39, 41, 53, 54, 57, 61, 62, 63, 64, 72, and 88.

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[92] Op. cit., pp. 16–18.

The following observations were made in the Maine quarries: A pegmatite dike crosses the diorite at Round Pond, in Lincoln County. (See p. 249, also Pl. X, *B*, of U. S. Geol. Survey Bull. 313.) At the Hallowell Granite Works quarry (p. 234) there is a 2-foot dike consisting of milk-white soda-lime and potash feldspars (oligoclase and microcline), smoky quartz, biotite and muscovite (black and white mica), and garnet. The feldspars, quartz, and micas attain a length of several inches. At the North Jay quarry (p. 214) the pegmatite dikes, which are as much as 2 feet 6 inches in width, consist of a milk-white potash feldspar, smoky quartz, biotite, and muscovite, the constituents measuring several inches in diameter. At the Clark Island (Rodgers) quarry (p. 241) there are two interesting pegmatite dikes with similar material of similar dimensions, together with black tourmaline and garnet. The granite at Fryeburg, near the New Hampshire line, abounds in pegmatite. At the Eagle gray granite quarry (p. 252 and fig. 63) two dikes, one 5 feet and the other 10 feet thick, alternate with granite 25 and 60 feet thick. The feldspar masses and crystals attain a length of 12 inches, and the biotite and muscovite crystals and the quartz masses a length of 6 inches. Small garnets are abundant. Mingled with the pegmatite is some fine-grained aplitic material. There is also considerable pegmatite at the Waldoboro quarry, in Lincoln County. (See p. 250 and fig. 16.) At the Willard Point quarry there is a 12-inch pegmatite dike of feldspar, quartz, muscovite, and black tourmaline, which has a banded structure. It is crossed by another dike half as thick with a difference in strike of 20°.

The following observations were made in New Hampshire:

At a quarry in Milford (p. 189; Pl. VIII, *A*) large dikes of pegmatite appear to proceed from the surface of a mass of quartz monzonite into an overlying granite gneiss. The pegmatite dikes at the Bailey quarry, in Allenstown, Merrimack County, contain black tourmaline and beryl. A thick dike of coarse garnetiferous pegmatite in the center of the Marlboro quarry, in Cheshire County, has a border made up largely of beryl and its biotite is in blades 1 foot long and 1 inch wide. This dike is reported to have yielded a garnet crystal over 6 inches in diameter and beryls of the same length. The pegmatite dikes of the Perry Sunapee quarry contain the usual black tourmaline and garnets.

The following observations were made in Rhode Island:

At the Klondike quarry, in Charlestown (Pl. XXXIV, *A*), large dikes of pegmatite appear to proceed from the surface of an intrusive quartz monzonite into an overlying granite gneiss. At the Redstone quarry, near Westerly, a pegmatite dike 5 to 10 feet thick runs the whole length of the quarry, 850 feet, with a dip of 10°, and consists of alternating reddish aplite and coarse pegma-

tite made up of reddish feldspar, smoky quartz, and biotite. Some of its surfaces are coated with drusy hematite. This dike overlies a fine-grained quartz monzonite and underlies a medium-grained biotite granite of earlier date than the monzonite. At the Chapman quarry, also near Westerly, the fine-grained quartz monzonite is cut by a pegmatite dike of very low dip, and 20 to 30 feet below it is a small aplite dike with like dip.

The following observations were made in the Vermont quarries:

At the Pirie quarry, near Barre, the biotite granite is cut by a pegmatite dike 3½ feet thick, consisting almost entirely of light bluish-gray feldspars having a 6-inch biotitic border on each side, with the axes of the biotite crystals at right angles to the course of the dike. At the Anderson quarry, near Barre, a 1-foot pegmatite dike intervenes between the granite and the slate capping, which is also injected with minute dikes of pegmatite as much as 4 feet in length. (See further p. 85 and figs. 11, 12.) At the Barney quarry, in Barre, a pegmatite dike follows the contact of granite and schist, and the granite, for a thickness of 15 feet from the schist, appears to be pegmatized in alternating bands. At the Bailey quarry, in Barre, pegmatite dikes, large and minute, penetrate the schist capping and a large schist inclusion and are associated with aplite. Some of the pegmatite dikelets, only 0.3 to 0.4 inch thick, run across the bedding foliation and then subdivide to pass at right angles within one of the little beds. The adjacent schist is unaltered. On Robeson Mountain, in Woodbury (p. 88), minute pegmatite dikes also proceed from the granite surface and penetrate the schist capping.

A very exceptional cylindrical dike of pegmatite penetrates the riebeckite-aegirite granite at the Ballou quarry, in Quincy, Mass., and a similar one was discovered about five years afterward in the Fallon quarry, about 600 feet south. (See map, Pl. XXIV.) These pegmatites and their minerals have been exhaustively studied by Palache and Warren and are described in three papers.[93] The dike at the Ballou quarry is vertical, roughly cylindrical, and about 2 feet in diameter. A horizontal section of it has for many years been exposed at the gradually deepening bottom of the quarry, which in 1906 had reached a depth of 150 feet. A block containing an entire cross section of this dike was shown to the writer in the yard

[93] Warren, C. H., Note on the occurrence of an interesting pegmatite in the granite of Quincy, Mass.: Am. Jour. Sci., 4th ser., vol. 28, pp. 449–452, 1909. Palache, Charles, and Warren, C. H., The chemical composition and crystallization of parisite and a new occurrence of it in the granite-pegmatites at Quincy, Mass, U. S. A., with notes on microcline, riebeckite, aegirite, ilmenite, octahedrite, fluorite, and wulfenite from the same locality: Am. Jour. Sci., 4th ser., vol. 31, pp. 533–557, 1911. Warren, C. H., and Palache, Charles, The pegmatites of the riebeckite-aegirite granite of Quincy, Mass., U. S. A.: their structure, minerals, and origin: Am. Acad. Arts and Sci. Proc., vol. 47, pp. 125–168, Boston, 1911.

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of the Quincy Granite Co. It has an outer rim with abundant blue-black riebeckite crystals slightly larger than those of the surrounding granite. Within this is an intermediate zone (specimen D, XXIX, 80, b) of light greenish-gray feldspar and slightly milky quartz (particles up to 0.8 inch in diameter), containing bright grass-green crystals of aegirite in sizes up to 1 by 0.5 inch, with some purple fluorite and rusty metallic spots. The center consists mainly of quartz, with coarse feldspar outside of it.

Under the microscope the feldspars prove to be orthoclase with a finely intergrown plagioclase, also particles of albite and probably oligoclase-albite. Both feldspars have the minute crystals of riebeckite and minute grains and prisms of aegirite typical of Quincy granite. The quartz has many fluidal cavities. There are slender aegirite crystals in feldspar and quartz. The riebeckite, is intergrown with aegirite, and ilmenite is somewhat plentiful. The feldspars are somewhat kaolinized, and there is some hematite and limonite stain. The brownish metallic areas of the middle zone consist of ilmenite, titanite, zircon in double pyramids, allanite, fluorite, aegirite, and quartz.

This cylindrical dike is thus a riebeckite-aegirite granite—that is, a granite containing varieties of amphibole and pyroxene rich in soda and ferric oxide but poor in alumina, magnesia, and line—and therefore resembles the surrounding granite, but its particles are much coarser and radially arranged; some of its accessory minerals are exceptional, and the others are more abundant. A polished complete section of the Ballou dike is in the collection of Harvard University.

The minerals identified by Palache and Warren in the pegmatite dikes of the Ballou and Fallon quarries include quartz in crystals, aegirite, riebeckite, crocidolite, zircon, fluorite, ilmenite, octahedrite, parisite,[94] beckelite,[94] wulfenite, molybdenite, chalcopyrite, galenite, sphalerite, hematite, secondary calcite, and ferruginous stain.

Pegmatitic quartz.—Besides these dikes of normal pegmatite there are dikes consisting largely of quartz of pegmatitic origin. At the old Bodwell Co.'s quarry on Cook's Mountain, near Redbeach, Maine, the red granite is traversed by a banded grayish quartz vein, about 18 inches thick, with a N. 25° W. course and vertical dip. It comprises three or in places four bands, which differ mainly in texture and are separated by more or less pyrite in fine particles. In places this vein divides into three smaller veins, each of which is from 3 to 4 inches thick. The quartz contains some purple fluorite (lime fluoride), as determined by W. T. Schaller, of this Survey, and a variable amount of a foliaceous lemon-colored mineral which Wirt Tassin, of the United States National Museum, has analyzed and determined as a new variety of sericite, resulting possibly from the alteration of a feldspar, and which is accompanied by another mineral, regarded by him as probably talc. Mr. Tassin's analysis and note follow:

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[94] Parisite and beckelite contain the rare elements cerium, lanthanum, and didymium.

Analysis of yellow foliated mineral (specimen D, XXVI, 105a, 1905).

Silica (SiO_2)	53.28
Alumina (Al_2O_3)	23.06
Ferric oxide (Fe_2O_3)	.10
Ferrous oxide (FeO)	4.30
Magnesia (MgO)	4.09
Soda (Na_2O)	.65
Potash (K_2O)	8.90
Water (H_2O)	6.00

The mineral is secondary mica, probably derived from feldspar (although this is merely a conjecture), and will approximate sericite in composition. It occurs in fine scales, occasionally compacted and then resembling serpentine. Luster, pearly; color, greenish yellow; hardness, 2.5; specific gravity, 2.79 at 20° C. It is associated in the vein with quartz, pyrite, purple fluorite, and another mineral which has a greasy luster and contains magnesia but which it was impossible to separate in a state of sufficient purity for analysis. This last mineral I believe to be talc.

At the Galvin quarry, in Quincy, Mass. (p. 325), the granite is cut at intervals of 2 to 10 feet by quartz veins up to 1 inch thick, each of which occupies the center of a belt of light granite 10 inches wide. Similar veins occur at intervals of 2 to 25 feet at the Field & Wild quarry (p. 326).

At the Blanchard quarry, in Uxbridge, Mass. (p. 352), the granite gneiss is crossed by veins of medium smoky quartz banded lengthwise with feldspar (specimen D, XXX, 114, c) and measuring up to 3 feet in thickness. The feldspar bands are 0.2 to 0.5 inch wide and the quartz 0.5 to 1.5 inches.

At the Milne quarry, at Barre, Vt., veins of smoky quartz with diagonal fractures occur at intervals of 3 feet. The granite for 0.2 inch next to the veins is largely feldspar. Along the edge of the vein there are bands of fibrous muscovite and in places streaks of granulated quartz.

BASIC DIKES.

Dikes of dark-greenish hard, dense rock (diabase, rarely basalt) are of very common occurrence in the granite quarries of Maine and Massachusetts. The courses of some of these dikes and their relations to the joints are shown in figures 4, 23, 44, 61, 63, 67, 71, 74, 75, 76, 77, 84. Some of them are represented in Plates VIII, *B*, XVI, *B*, and XXVII, *A*, *B*.

The following observations were made on the Maine dikes:

The dikes are vertical or nearly so and range in width from 1 inch to 7 feet or more, cutting the granite sheets with mathematical definiteness. Plate XVI, *B*, shows one of these dikes on Mount Desert, which has a course N. 15° W. and has been faulted from east to west, or west to east, along a gently inclined sheet with a displacement of 16 inches. A few feet beyond this point the same dike has been

faulted along a northeasterly vertical joint, with a displacement of 5 feet. Although it might seem that this dike was injected into the granite before the sheet structure was formed, it is quite possible that the sheet structure preceded the dike and that later faulting affected both the sheets and the dike, cracking the dike along the sheets where it did not actually fault the dike.

Most of these dikes are so firmly welded to the granite that hand specimens one-half granite and one-half diabase are readily obtained. Thin sections of the glassy rims of dikes at Bryant Pond and Fryeburg show that the dike sent out microscopic branches for short distances into the granite, in places surrounding some of its quartz particles. A dike at the Dunbar Bros.' quarry, near Sullivan (p. 231), 16 to 18 inches wide, has a 0.25-inch border of light-green epidote, derived from the alteration of its glassy rim. These glassy borders are due to the rapid cooling of the material at its contact with the cold granite. A few typical thin sections of these dikes will be described in detail.

The center of a 7-foot dike at the Mosquito Mountain quarry, near Frankfort (p. 258), shows a network of minute lath-shaped crystals of lime-soda feldspar (labradorite) partly altered to a white mica, in the meshes of which is a green hornblende; also some magnetite in fine particles, and pyrite, with accessory titanite, apatite, and secondary epidote.

A 4-inch dike at the Havey (Whaleback) quarry, in North Sullivan, shows a groundmass of fine hornblende and feldspar (plagioclase), in incomplete crystals, with magnetite and thinly disseminated larger crystals of hornblende and lime-soda feldspar (labradorite), some large quartz particles, and a little pyrite. One feldspar crystal is almost completely altered to a white mica.

A 2½-foot dike at the Campbell & Macomber quarry, on the west side of Somes Sound, on Mount Desert (p. 223), shows a groundmass of fine hornblende and feldspar (plagioclase) in incomplete crystals, with magnetite (?), pyrite partly altered to limonite, and lime-soda feldspar (labradorite). Some of the particles of the feldspar measure 0.1 inch in length by 0.02 inch in width and are largely altered to kaolin and a white mica. The hornblende in all these dikes is regarded as a product of the alteration of augite.

The geologic age of these dikes has not been precisely determined. They are considerably more recent than the granite they traverse or the dikes of aplite and pegmatite which cut the granite. In Plate VIII, *B*, is shown one of these diabase dikes crossing both a vein of pegmatite and a mass of diorite ("black granite"), at Round Pond, in Lincoln County, Maine.[95] (See p. 249.)

The following observations were made in the granite quarries of Massachusetts:

At the Granite Railway quarry, in West Quincy, there is a 15-foot diabase dike striking about N. 75° W. in which the feldspar is altered

[95] Some of the dikes of that part of the coast have been described by F. Bascom: On some dikes in the vicinity of Johns Bay, Maine: Am. Geologist, vol. 23, pp. 275–280, pls. 9–11, 1897. See also Keeley, F. J., Notes on some igneous rocks at Ogunquit, Maine, and Pigeon Cove, Mass.: Acad. Nat. Sci. Philadelphia Proc., vol. 66, pt. 1, pp. 3–8, 1914.

to a white mica. It has a greenish rim, in which the augite is all chloritized. At the Merry Mount quarry, on the North Commons, a 5-foot dike, striking about north, appears to be a garnetiferous biotite lamprophyre.

The conspicuous feature of the Rockport quarries on Cape Ann is the large number of basic dikes that traverse them. The geology of Cape Ann has been interestingly described by Shaler and Tarr.[96] The entire Cape is represented on Shaler's map (Pl. LXXVII) as of granite but traversed at very frequent intervals by diabase dikes and at a few points by quartz porphyry dikes. The basic dikes may be Triassic. They range from 0.25 inch to 40 feet in width. Of 361 observed by Shaler and Tarr 266 lie in the northwest quadrant and more than half in the 45° between north and northwest. Those writers conclude from numerous observations of dike and joint courses that the number of dikes does not appear to have been determined by the number of incipient fissures afforded by the joints—in other words, "that the conditions which guided the direction of the dikes were probably due to some feature or condition not inherent in the joints themselves." Some of these dikes are shown in Plate XXVII, *A* and *B*. Their courses are given in the quarry descriptions. One attains a thickness of 18 feet. They are mostly diabase (soda-lime feldspar, augite more or less altered to hornblende, magnetite, and biotite). One was found to contain both augite and hornblende but no mica. The dike matter was erupted through deeply parted joints. Contemporaneous with them was the irregular-shaped injection described beyond and shown in Plate XXVII, *B*.

The Pigeon Cove diabase porphyry quarry is on a dike of altered diabase porphyry, 18 feet wide, which was represented by Shaler[97] and Tarr as exposed for half a mile on the hillock west of Pigeon Cove, with a N. 21° W. course, also as reappearing in Rockport 0.75 mile west of Gap Head with a N. 9° W. course. Washington[98] refers to this dike as cutting the quarry pit at Pigeon Cove and describes it microscopically as a labradorite porphyry.

Plate XXV, *B*, from a photograph of a polished ball 2 feet 7 inches in diameter, quarried and finished by Fuller, Foley & Co., of West Quincy, shows its general character.

This diabase porphyry (specimens D, XXIX, 89, a, b) has a very dark green or black fine-grained groundmass, with porphyritic feldspars of medium greenish-gray color, measuring from 0.2 to 4.42 inches in length by about 0.78 inch in width. Many of the crystals are from 1 to 2 inches long. Their striation shows plainly.

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[96] See Shaler, N. S., The geology of Cape Ann, Mass.: U. S. Geol. Survey Ninth Ann. Rept., pp. 529–611, 1899.

[97] Op. cit., p. 609, pl. 77.

[98] Washington, H. S., The petrographical province of Essex County, Mass.: Jour. Geology, vol. 7, p. 290, 1899.

The groundmass consists of the following minerals, in descending order of abundance: Lime-soda feldspar (andesine-labradorite) partly micacized, augite largely altered to a green hornblende and chlorite, biotite (black mica), magnetite, and apatite; rarely a little secondary calcite.

A dike of unusual form, composed of fine-grained black hornblende diabase, is exposed at the bottom of the Rockport Granite Co.'s "Deep Pit," near Bay View, on Cape Ann, 195 feet below the surface, as shown in Plate XXVII, *B*, and in more detail in figure 3. It dips north. Its original upper surface, 30 feet above its present surface, is reported as not over 8 feet in diameter. As shown in Plate XXVII, *B*, the quarry is traversed by two intersecting basic dikes. The one nearest to this mass, 10 feet west of it, is not a hornblende diabase (ophitic texture with hornblende and biotite), but a lamprophyre without biotite (porphyritic texture with augite). The large dike on the east side, which from its dip must traverse the granite about 80 feet east of the mass, proves to be also a hornblende diabase. The connection of the central mass will, therefore, if excavations proceed deep enough, very probably be found to be with the dike on the east, not with that on the west.

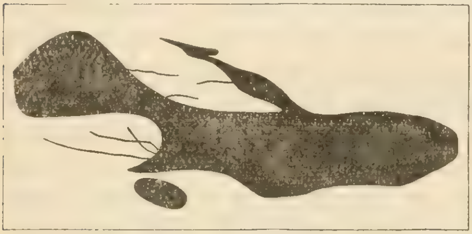

FIGURE 3.—Diagrammatic sketch of horizontal cross section of injection of hornblende diabase at Deep Pit granite quarry, near Bay View, on Cape Ann, Mass. Length, north to south, 25 feet, and east to west 8 feet. The fine ramifications are 3 feet by 1 inch in greatest size.

Thin sections of the fine-grained rim of one of the dikelets protruding from this mass and of the granite next to it bring out interesting facts. The rim sends out branches 0.125–0.25 millimeter long into the granite. In places both rocks are dovetailed into each other. The rim consists of minute roundish particles of hornblende and incipient crystals of feldspar and fine particles of magnetite. There are crowds of apatite crystals along the contact and a little secondary calcite. In one place the hornblende and magnetite of the dike are thickly disseminated in the granite; in another both rocks are merged in one containing the minerals of both.

This diabase mass appears to have been injected at the time of the intrusion of the other diabase dikes of the Cape and to owe its shape to an irregular east-west fissure with a northern inclination. That the intrusion probably took place under considerable pressure and heat is shown by the commingling of the minerals of both rocks along their contact.

Some interesting dikes were found in the quarries of Uxbridge, New Bedford, Fall River, and Hingham. The elongated porphyritic biotite granite gneiss of the Blanchard quarry in Uxbridge (p. 353) is cut by an amphibolite dike up to 18 inches thick, the schistosity of

which strikes at an angle of 33° with that of the inclosing gneiss. This dike consists of feather-rimmed crystals of amphibole up to 1 inch in length in a matrix of biotite with interspersed quartz grains and minute slender crystals or strings of lenses of zoisite. In places, however, along the edges the matrix is of quartz, biotite, epidote, and oligoclase-andesine. The dike was originally a porphyritic mica diorite. It cuts dikes of pegmatite and of aplite.

At the Sullivan quarries, near New Bedford (p. 285), is an interesting complex of dikes of various sorts and ages whose courses are shown in figure 4. The rock is a slightly gneissoid biotite-muscovite granite of light pinkish-gray color.

The central dike A, with northeast course and up to a foot thick, is a dark-greenish chlorite schist (specimen D, XXX, 121, c) consisting of chlorite, probably after hornblende, in parallel arrangement, micacized plagioclase, quartz, and microcline. Its accessory minerals are pyrite, magnetite, purple fluorite, apatite, and biotite, and its secondary minerals epidote, carbonate, and hematite from the magnetite. This dike was evidently originally a diorite. Dike B, on the south wall, with a N. 70° E. course and a dip of 60° N. 20° W., over 2 feet thick, is a dark-grayish mica diorite schist (specimen 121, d), consisting, in descending order of abundance, of andesine, biotite, epidote, and muscovite. This was originally a mica diorite. Dike C, on the north wall, with a N. 60° E. course and vertical dip, up to 3 feet thick, is a black fine-grained mica diorite schist (specimen 121, f), consisting, in descending order of abundance, of biotite, oligoclase, microcline, quartz, and epidote. This also was originally a mica diorite. It differs from dike B in being more micaceous and in containing no muscovite. The edge of this dike (specimen 121, g), for a thickness of a few inches, consists of brecciated grayish feldspars up to 0.3 inch in diameter in a matrix of biotite. At the extreme edge this breccia passes into a mass of the same feldspar with a little quartz and still less biotite. The more glassy rim of the dike resisted the pressure which brecciated its inner border and converted its central part into a schist. Dike D, near the west wall, with a northwest course and steep dip, 3 inches thick, is pegmatite. It intersects the central chlorite schist (diorite) dike. Finally, dike E, on the west wall, with a N. 10° E. course, up to 2 feet thick, is a diabase (specimen 121, e) with ophitic texture, consisting, in descending order of abundance, of andesine, pyroxene, serpentine (probably after olivine), and magnetite or ilmenite with a little carbonate and biotite. This was presumably an olivine diabase.

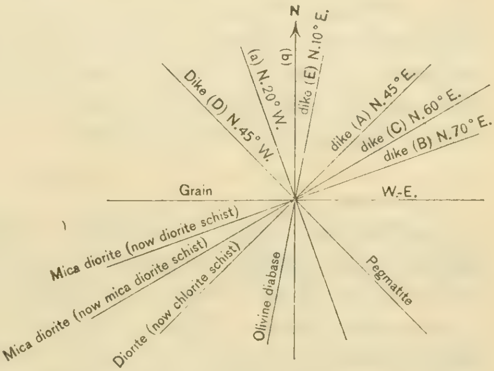

FIGURE 4.—Structure and dikes at Sullivan quarries, New Bedford, Mass.

The evidence from these dikes shows that the granite was injected with dikes of diorite and mica diorite. Later both the granite and

the dikes were crossed by pegmatite. After dynamic metamorphism had altered the diorites to schists they were traversed by a diabase dike in which the only change has been the serpentinization of the olivine and the micacization of the andesine.

Another basic dike in these quarries is an altered but not metamorphosed lamprophyre, in the gneissoid biotite granite of the Beattie & Wilcox quarry, at Fall River (p. 283), which Whitman Cross, of this Survey, determines as vogesite. It has much augite and brown hornblende, biotite, and magnetite in a feldspathic base, probably of orthoclase, also a few porphyritic crystals of olivine altered to serpentine.

There is also a slightly altered diabase dike crossing the aplite of the Miller quarry, in Hingham (p. 338).

The reddish biotite granite of the Redstone quarry, at Westerly, R. I., is cut by a 6-inch dike of porphyritic olivine diabase, probably of Triassic age. Near by in the same granite is a vertical meandering mass of coarse biotite schist with kaolinized feldspar which is either a basic segregation elongated in the direction of the flow or else a very ancient metamorphosed dike.

BASIC SCHISTOSE DIKES.

The dikes ordinarily occurring in granite are either acidic, including pegmatite, aplite, and granite proper, or basic. If a granite after the intrusion of such dikes is itself subjected to metamorphism so as to become schistose—that is, a gneiss—then these various dikes will also become more or less schistose. In the granite of Milford, Mass., however, there are schistose basic dikes without an equally gneissic or a parallel gneissic structure in the granite.

At the Cutting quarry (fig. 82) the west wall is formed by a vertical dikelike mass of biotite schist 2 feet thick striking N. 25° W. The east wall is formed by a heading of almost identical strike, N. 20° W., but dipping 70° E. As shown in the figure, neither of the flow directions nor the trend of rift or grain corresponds to the strike of the schist dike. The only corresponding structure is that of the heading and the inclosing walls of the dike. At the West quarry, 1½ miles south-southwest of the Cutting quarry, there are two dikes of similar schist, one striking N. 67° W. and dipping 65° NNE., the other striking about N. 45° W. with nearly vertical dip. The nearest parallel structure is a joint striking N. 60° W. and dipping 47° SSW. At the Massachusetts Pink quarry 0.6 mile southwest of the Cutting quarry, there is another schist dike, 2 feet thick, striking N. 3° W. and dipping 55° E., without other corresponding kinds of structure. The general schistosity of all these dikes is parallel to the joint faces which inclose them, and no merging between granite and schist was observed. Emerson and Perry (p. 340) note the rudely parallel films

of biotite in the granite, which give it a gneissoid look but which seem to be partly due to flow structure, and they note the undulatory extinction of the fractured quartz particles as showing a state of strain. The granular structure of the quartz areas is very noticeable on a polished face, and this very possibly resulted from the pressure which converted the dikes into schist.

In thin section the fine-grained dark greenish-gray schist of the Cutting quarry dike is seen to consist of biotite, quartz, epidote in roundish grains from the alteration of feldspar, and a little pyrite. The slightly more greenish schist of the dike at the West quarry consists of hornblende, quartz, biotite, epidote, and zoisite from alteration of feldspar, a brownish cloudy mineral (leucoxene?), and pyrite altered to limonite. Both are evidently altered dikes of mica diorite—that is, diorite schist.

Emerson and Perry regard these dikes as a "basic differentiate of the Milford granite" (p. 340, footnote 51).

At the Sullivan quarry, in New Bedford, Mass. (p. 285, fig. 4), a very slightly gneissoid biotite-muscovite granite is cut by a mica diorite schist dike, the schistosity of which was evidently also due to the pressure of the dike walls. In these places the dike material was intruded between parted joints in the granite. It is evident that the change of the eruptive into schist and the alinement of its particles with reference to the inclosing walls were brought about chiefly by compression which, although sufficient to metamorphose the dikes, affected the granite but slightly; nor was the vertical pressure sufficient to plicate the dike or its inclosing walls.

Thus a basic dike traversing a mass of granite in a highly inclined position may under lateral compression become schistose without the inclosing granite acquiring a corresponding schistosity.

Soon after the first publication of the above description Clough, Crampton, and Fleet, of the British Geological Survey, found similar dikes in Scotland which they define as foliated by dynamic metamorphism under the pressure of the inclosing granite.[99]

EFFECT OF BASIC DIKES ON GRANITE.

Generally these dikes produced little or no effect upon the granite into which they were injected, but in some places the heat of the dike material developed minute cracks in the quartz and feldspar, in which secondary minerals were formed, darkening the granite, or minute particles of hematite were disseminated in the feldspars, reddening the stone. In other places the granite on either side of the dike became closely fissured in a direction parallel to it.

Thus at the Robertson quarry, in Franklin, Maine, the granite for a space of 10 feet on each side of a vertical 3-foot diabase dike is

[99] See Clough, C. T., Crampton, C. B., and Fleet, J. S., The augen gneiss and Moine sediments of Ross-shire: Geol. Mag., new ser., decade 5, vol. 7, pp. 337–345, 1910.

altered from medium to dark gray and the rock is filled with close joints dipping at low angles. In thin section the quartz particles and some of the feldspars are crossed by roughly parallel cracks 0.25–1.25 millimeters apart.

At the Flat Ledge quarry, in Rockport, Mass., the granite on either side of a diabase dike is darkened. A thin section of the darkened rock shows it to be crossed by minute parallel or converging fractures, 0.004–0.04 inch apart. The intervening space is crowded with angular slivers, the walls of the fractures are coated with chlorite, and the adjacent feldspars are altered to mica.

At the Tonella (King) quarry, in Milford, N. H., the granite is cut by a 2-foot 6-inch dike of augite camptonite. For 8 feet on one side of the dike the granite has a marked pinkish tint due to minute specks of hematite in the feldspar. At the Pease quarry, in the same town, the granite has been reddened and darkened for a thickness of 50 feet, apparently by basic dikes. (See p. 185.)

The light-gray granite at the Bailey quarry, in Allenstown, N. H. (p. 193), is cut by a hornblende diabase dike 3 to 4 feet thick, and the granite for 14 feet on one side and 2 feet on the other has become greenish gray owing to the slight chloritization of its plagioclase feldspars.

The granite for a foot on each side of a basic dike in Ryegate, Vt., has close joints parallel to the dike. C. H. Richardson has published a photograph of a zone of laminated (close-jointed) granite adjacent to a basalt dike exposed in a newly opened quarry in Woodbury, Vt.[1]

SEGREGATIONS ("KNOTS").

BASIC SEGREGATIONS.

Quarrymen know too well that granite is commonly disfigured by gray or black "knots" of circular or oval outline, ranging in diameter from 0.5 inch to 3 feet and exceptionally even 10 feet. These were studied by geologists long ago. They are finer grained than the granite in which they occur, contain nearly 10 per cent less silica, much more black mica or hornblende (which accounts for their darkness), and a little more soda-lime feldspar, and their specific gravity is about 0.09 per cent higher.[2]

In none of the knots is there a definite boundary separating them from the granite, except such as is caused by the change in the pro-

[1] See Vermont State Geologist Ninth Rept., pl. 67, a, 1914; also p. 151 of this bulletin.

[2] Phillips, J. A., On concretionary patches and fragments of other rocks contained in granite: Geol. Soc. London Quart. Jour., vol. 36, pp. 1–22, pl. 1, 1880. Merrill, G. P., On the black nodules or so-called inclusions in the Maine granite: U. S. Nat. Mus. Proc., vol. 6, pp. 137–141, 1883. Grimsley, G. P., Basic segregations: The granites of Cecil County in northeastern Maryland: Am. Soc. Nat. Hist. Jour., April and July, 1894. Daly, R. A., Basic segregations: The geology of Ascutney Mountain, Vt.: U. S. Geol. Survey Bull. 209, p. 164, 1903.

portionate abundance of the darker minerals. The cause of knots is not perfectly understood. They are collections (segregations) generally of the darker, heavier iron-magnesia minerals that were formed before the rock passed into a crystalline state.

Plate XIII, *A*, shows 12 knots in the vertical cuts at Crabtree & Havey's quarry, in Sullivan, Me. As the strength and durability of the stone are in no wise affected by the "knots," the blocks containing them are used for curbing, crossings, or other constructions where color is not taken into consideration.

A thin section of a very dark gray knot from this quarry shows a much greater abundance of biotite than the granite. The feldspar and the biotite particles in the knot measure up to 0.5 millimeter (0.02 inch), whereas in the granite the feldspar measures up to 2.25 millimeters and the biotite up to 0.75 millimeter.

A segregation from the Palmer quarry, on Vinalhaven, Maine, is of medium-gray shade, with a very fine grained groundmass inclosing porphyritic buff-pinkish feldspars and smoky quartz particles up to about 0.25 inch in diameter. The groundmass consists of quartz, potash feldspar (microcline), soda-lime feldspar, black mica, and hornblende in particles ranging in size from 0.075 to 0.5 millimeter. The porphyritic particles are of quartz, potash feldspar, or soda-lime feldspar, and hornblende, and measure from 0.75 millimeter up.

A very dark, almost black knot from the Sands quarry, also on Vinalhaven, consists of crowded particles of hornblende and biotite, which compose one-half the knot, the rest being mostly soda-lime feldspar and quartz. A spherical knot at the same quarry was 2½ feet in diameter; a similar one, at the Webster quarry, also in Vinalhaven, was 5 feet in diameter. One at the Mount Waldo quarry, 6 by 3 feet, consists of a medium-gray groundmass with porphyritic feldspars up to 0.75 inch and biotite scales up to 0.05 inch. One at the Andrews quarries, near Biddeford (p. 275), is 10 feet long. At another Biddeford quarry the knots are egg-shaped and occur in clusters. At the Tayntor quarry, in Hallowell, there is a belt 5 to 25 feet wide, with a course N. 10° E., in which knots are abundant. This crosses the flow structure, which strikes N. 35° W.

The segregations in the granite exposed in the quarries at Quincy, Mass., are of three kinds:

One is very fine grained, aplitic, dark bluish gray, with a matrix of potash feldspar, quartz, and more or less soda-lime feldspar (albite to oligoclase-albite), with particles from 0.025 to 0.3 millimeter, containing porphyritic crystals of aegirite (with some riebeckite) up to 0.84 by 0.09 millimeter, which appear as if corroded. Zircon, magnetite or ilmenite, and abundant apatite occur as accessories. There are also minute crystals of riebeckite and titanite, with secondary limonite and carbonate. The two other kinds belong in the acidic group described beyond.

The dimensions of the large knots given in the quarry descriptions were obtained from the foremen. It is assumed that the knots are segregations, not inclusions. The dimensions range from 0.5 inch to 2 feet by 1 foot 6 inches, 2 feet 6 inches by 2 feet 6 inches, 3 feet by 4 inches, and 6 feet by 2 feet. The knots are usually small and roundish or elliptical.

ACIDIC SEGREGATIONS.

Segregations in granite consist generally of the darker, more ferruginous minerals, but some are lighter or of the same shade as the surrounding granite. Among these are two varieties in the Quincy granite.

Those of one variety are medium grained and medium gray, lighter or of the same shade as the inclosing granite. These are identical with the granite, but the orthoclase tends to complete its crystals. One such knot contains a complete section of an aegirite crystal in the center of a quartz area many times its size. Another has secondary orange fibrous hornblende growing on aegirite. Zircon and fluorite are accessory. The other variety comprises some muddy yellow to greenish knots consisting of potash feldspar (orthoclase) minutely intergrown with soda-lime feldspar, in twins from 0.2 to 1 millimeter long, and quartz with aegirite and riebeckite, which usually appear to fill spaces between the other minerals. The soda silicates are more or less altered to fibrous muscovite and carbonate; the feldspars are also streaked with white mica and contain secondary epidote. The usual magnetite, apatite, and riebeckite are present.

Segregations are not uncommon in the granite of Rockport, Mass., but at Halibut Point, the extreme north end of Cape Ann, in the Babson Farm quarry, there is one of unusual character. It is 8 by 4 by 2½ feet and consists mainly of feldspar and quartz. The feldspar is a somewhat kaolinized light-grayish potash feldspar (microcline) minutely intergrown with soda-lime feldspar (oligoclase-albite) and containing a few particles of quartz. The cleavage of the feldspar has in places a marked curvature. The quartz is amethystine smoky, in particles up to 2 feet across, and has cavities from 0.00285 to 0.0285 millimeter in diameter. In the center of this knot is a mass, 6 by 2 inches, of a yellow-brownish mineral of the augite group, which Johannsen determines as bronzite, a silicate of magnesia with 60 per cent of silica and 40 per cent of magnesia.

ORBICULAR GRANITE.

The white quartz (muscovite-biotite) monzonite of Bethel, Vt., is crossed on the east side of the Ellis quarry (see p. 158 and fig. 36) by a belt a few feet thick which has a marked flow structure consisting of vertical micaceous bands 0.5 inch or less wide, a foot or more apart, and with a northerly strike. The micas in these bands tend to arrange themselves about the quartz and feldspar particles and are roughly parallel. Near the granite surface there is a branching mass of wrinkled bronze-colored micaceous material a foot thick lying in the plane of flowage. Biotite appears to be the chief constituent in this mass. In thin section it consists of coarse stringers of an olive-greenish biotite, more or less completely surrounding particles of quartz and soda-lime feldspar. There are also small

scales of muscovite penetrating the quartz and feldspar particles. In this same flowage belt there are crowds of elliptical discoid nodules of bronze-colored mica from 0.5 to 2 by 1.5 inches and about 0.2 inch thick. The surfaces of these disks are either longitudinally or concentrically corrugated. Most of these nodules are discoid, but some of the smaller ones are nut shaped, resembling those in the well-known butternut granite of Craftsbury and Northfield, Vt.[3] Aside from their discoid form, the noticeable features of the Bethel nodules are that they lie in sheets parallel to the flow structure and that the major axes of the disks are parallel to the micaceous flowage bands. Plate III, *A*, is made from a photograph of a hand specimen containing one of the larger disks. The white quartz monzonite of Plymouth, Vt. (p. 161), also contains a few of these discoid nodules.

The attention of geologists was first called to the nodular granite of Craftsbury ("Craftsbury pudding granite") by Hitchcock and Hager in 1861. It was next described by Hawes in 1878[4] and in greater detail by Chrusthov in 1885,[5] and again by the same geologist in an elaborate monograph in 1894.[6] He found that the nodules contained over twice as much calcite as the granite. As both the granite and the nodules of Craftsbury differ from those of Bethel, his inferences do not exactly apply to the Bethel nodules. But a conclusion of Frosterus from the study of a nodular granite in Finland applies well to that of Bethel and shows the real significance of its nodules. It is that the nodules are basic segregations lying in a more basic part of the granite, indicating that the orbicular structure is simply a basic flowage band ("Schliere") and that the nodules themselves lie in this as still more basic segregations.[7]

The nodules in orbicular granite vary greatly in composition, size, and structure. Orbicular granites have been described from Bohemia, California, Corsica, Finland, France, Germany, Greece, Ireland, North Carolina, Norway, Ontario, Portugal, Rhode Island, Sardinia, Scotland, and Sweden. The literature of the subject is already large, embracing 47 papers and probably more.[8]

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[3] See Hitchcock, Edward, and others, Report on the geology of Vermont, vol. 2, pp. 563, 564, 721, 1861; also Dale, T. N., U. S. Geol. Survey Bull. 275, p. 90, 1906; Perkins, G. H., Vermont State Geologist Fifth Rept., p. 108, pl. 32, fig. 2, 1906.

[4] Hawes, G., Geology of New Hampshire (by C. H. Hitchcock), vol. 3, pt. 4, p. 203, pl. 11, fig. 4, 1878.

[5] Chrusthov, K. D., Note sur le granite variolitique de Craftsbury en Amérique: Soc. min. France Bull., vol. 8, pp. 132–141, 1885.

[6] Ueber holokrystalline makrovariolitische Gesteine: Acad. imp. sci. St.-Pétersbourg Mém., ser. 7, vol. 42, No. 3, Pudding granit von Craftsbury, Vt., pp. 132–146, pl. 2, fig. 9, and pl. 3, fig. 22, 1894.

[7] Frosterus, Benjamin, Ueber ein neues Vorkommnis von Kugelgranit unfern Wirvik bei Borga in Finland, nebst Bemerkungen über ähnliche Bildungen: Min. pet. Mitt., vol. 13, pt. 3, p. 187, 1893.

[8] See Zirkel, F., Lehrbuch der Petrographie, 2d ed., vol. 2, Kugelbildung, pp. 50, 51, 1894; also Rosenbusch, H., Mikroskopische Physiographie der Mineralien und Gesteine, 4th ed., vol. 2, Kugelstruktur, pp. 85–94, 1907.

GEODES.

Small cavities lined with crystals occur in granite. They are uncommon in the New England quarries, but at the Bodwell Granite Co.'s quarry, near Jonesboro, Maine (p. 268), there are several about a foot in diameter, lined with quartz crystals and epidote. The center of some of these is filled with calcite in very obtuse rhombohedra half an inch across. The large aplite vein at the same quarry has many irregular openings lined with crystals of feldspar and muscovite. At the Machias Granite Co.'s quarry, near Marshfield, Maine (p. 271), there are several geodes up to 6 inches in diameter, lined with crystals of feldspar and amethyst, with the central space filled with chlorite, epidote, fluorite, and calcite.

At the Redstone quarry, Conway, N. H. (p. 168), there are lenticular geodes, mainly of intergrown quartz and feldspar surrounded by a half-inch band of aplite. These geodes are lined with crystals of smoky amethystine quartz and orthoclase incrusted with chlorite and calcite. Some obtuse rhombs of calcite are 0.5 inch wide.

Such cavities are attributed to bubbles of steam or gas that were in the rock while it was molten and that gave room for the growth of crystals of the minerals of the granite and its accompanying fluorite and later became filled with secondary chlorite, epidote, and calcite.

INCLUSIONS.

Not to be confounded with "knots," although some of them are equally dark and occur near by, are irregular or angular particles of various rocks generally schistose, which the granite incorporated into itself during its intrusion. They can usually be distinguished from the knots by their different microscopic texture.

Inclusions are important, for they are specimens of the rocks that originally overlay the granite and they indicate the relative age of the intrusion. The process of the formation of an inclusion of mica slate is shown in figure 11.

In Connecticut, at the Stony Creek quarries, the inclusions consist of diorite gneiss and mica diorite gneiss. At the Hoadly Point east quarry an inclusion of mica diorite gneiss appears to have been elongated in the direction of the flow structure. Inclusions abound at the Millstone quarry (p. 396). One of banded biotite gneiss, 20 by 8½ inches, is shown in figure 84, *b*. Another of the same gneiss, 20 by 20 feet, has a very iregular outline, with small outlying fragments and adjoins a 6 by 3 foot mass of pegmatite with particles as much as 5 inches across. This mass and a smaller inclusion are shown in figure 90, *d*. The granite is somewhat banded about the large inclusion Another, near the northwest end and bottom of the quarry, measures 35 by 25 feet. It is a black diorite gneiss (specimen D, XXX, 6, *h*)

consisting of oligoclase-andesine, hornblende, quartz, and biotite, with accessory titanite. It is crossed by quartz veins, some of which start at the granite, others within the granite. A vertical pegmatite dike, 3 to 5 feet wide, in the upper granite mass referred to, contains an inclusion of biotite gneiss about 5 feet by 6 inches, with its long axis in vertical position. (See fig. 90, *a*.)

In the Maine quarries the inclusions range from an inch to 40 feet in length. Part of the jagged lower edge of an inclusion in granite at Freeport (p. 211) is shown in Plate XV, *B*. It is a mass of biotite schist between 30 and 40 feet long and 3 feet thick, striking north and dipping 35° E. In quarrying, this mass has been cut from east to west. Under the microscope this is a coarse biotite-quartz-feldspar (oligoclase) schist, probably of sedimentary origin.

The following inclusions were noticed in the Massachusetts granite gneiss and granite quarries:

The muscovite-biotite granite gneiss of the Rafferty quarry, in Groton (p. 308), contains several inclusions, the largest of which, triangular in outline, measures 30 feet on one side and 8 feet on another. This rock (specimen D, XXX, 100, a) is a dark-gray biotite granite gneiss with porphyritic feldspars up to 0.6 inch. Its quartz is granulated like that of the inclosing gneiss. Both gneisses are crossed by pegmatite dike, and aplite occurs also in both.

The muscovite-biotite-quartz monzonite gneiss of the Palmer quarry, in Westford (p. 312), has a lenticular inclusion, 3 feet by 3 inches, of very fine grained, evenly foliated quartz-biotite schist with some cloudy particles (much kaolinized feldspar?) also a little muscovite and zoisite. This rock may be of sedimentary origin. The gneiss at the Merrill quarry, in the same town (p. 310), also contains small dark finely banded inclusions.

The quartz monzonite of Barker Hill, in West Townsend (p. 314), has inclusions up to 4 feet across of a fine-grained biotite gneiss, probably a quartz-mica diorite gneiss like those in the quartz monzonite of the O'Rourke quarry, in Brookline, N. H., about 5 miles to the northeast (p. 192).

The fine-grained muscovite-biotite granite of Becket (p. 281) contains an 8 by 10 foot inclusion of a coarse muscovite-biotite granite gneiss.

The following inclusions occur in the New Hampshire granite quarries: At Concord, in the center of the now abandoned Crowley quarry is an inclusion of dark banded biotite-muscovite-oligoclase gneiss of slight purplish hue. It was originally 30 feet high and pointed at the top. It measures 30 feet in diameter at the base, which is nearly round on one side but rectangular on the other. A 2-inch pegmatite dike crosses the schistosity of the gneiss but ends abruptly at the granite contact. Another part of this inclusion consists of por-

phyritic granite with feldspars an inch long. At Milford, in the Daniels quarry, a roughly diamond-shaped inclusion of gneiss, over 3 feet in diameter, has a flow structure about it parallel to its surface, showing that while the plastic material was adjusting itself to the foreign body a zonal rearrangement of the mineral constituents of the granite took place.

Among the notable features of Vermont granite quarries are the schist inclusions. Those at Barre have been briefly referred to by Finlay.[9] Eighteen schist inclusions were noticed by the writer in the Barre quarries. There are three at quarry 32 (Pl. II); one of these, 25 by 10 by 10 feet, has a foliation striking N. 30° W. and dipping 60° E.; another is 20 by 8 by 5 feet. The granite is slightly darker for a space of 7 feet from these inclusions. At quarry 25 several measure up to 8 by 2 feet. At quarry 8 two are 10 by 6 by 2 to 3 feet. One at quarry 6 is 20 by 5 feet. One at quarry 10 is 30 by 3 feet, tapering. The largest was at the Boutwell quarry, No. 1, measuring 57 by 10 by over 6 feet, with a foliation striking N. 10° E. and dipping 55° W. Another, 10 by 8 feet, has a foliation striking north and dipping west. Some of these do not seem to have suffered much horizontal displacement, for their foliation nearly agrees with that of the schist capping. In others it differs greatly.

The larger Boutwell quarry inclusion was examined in detail. Parts of it are lustrous dark-gray muscovite-biotite-quartz schist spangled with biotite flakes 0.15 inch long and with garnets measuring about 0.05 inch. Parts of it consist of small beds of medium greenish-gray fine-grained quartzite (grains up to 0.2 inch) alternating with dark beds of quartz-biotite schist. The quartzite bands contain plates of green hornblende (up to 0.75 by 0.37 millimeter) and larger garnets which inclose the quartz grains of the rock. The schist bands contain similar plates of biotite lying transverse to the bedding and the foliation. Both kinds of bands contain lenses of carbonate (up to 0.37 millimeter) and irregular particles and crystals of zoisite and epidote. As the schists of Barre away from the granite are spangled with various minerals (see p. 123) it is hardly possible to determine which if any of the isolated minerals in this mass was formed at the time of the granitic intrusion. The hornblende and garnet may have been. A few inches of the under side of this inclusion consist of interbanded granite and schist, the schist having evidently at the time of the intrusion been broken into slivers along its schistosity, and the semiliquid granite having been forced in between them. The specimen in Plate III *B*, at the left, is from this point. It shows two minute dikes of granite, 0.5 to 1.2 inches wide, penetrating the schist and ramifying. The main dikes follow the foliation, but the minor branches form very acute angles with it and taper out. A thin section made across one of these little dikes and the inclosing schist shows the former to be the typical biotite granite of Barre and the latter a quartz-muscovite-biotite schist spangled with biotite plates (up to 0.1 inch). The quartz of the granite shows marked strain effects. The demarcation between granite and schist is sharp, and no effect of granite upon schist appears.

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[9] Finlay, G. I., The granite area of Barre, Vt.: Vermont State Geologist Third Rept., p. 51, 1902.

At the Bailey quarry (No. 6, Pl. II) an inclusion lies very near the schist capping. As the bedding of the inclusion strikes nearly east and that of the capping N. 20°–60° E., the inclusion has been revolved. Both capping and inclusion have been shattered and injected with aplite and pegmatite.

At the Morrison quarry, on Blue Mountain, in Ryegate, two schist inclusions were noticed measuring 8 by 4 feet and 3 feet by 1 foot. The edge of the larger one is injected with granite, which fills lenticular spaces, as shown in Plate III, *B*, at the right. In another specimen the schist has sharp plications, 5 inches high, with lenses of smoky quartz parallel to them, but the nearest edge of the inclusion is nearly a plane surface.

A thin section, 1.6 by 0.7 inch, across the edge of this inclusion shows a little granite dike, the quartz monzonite of the quarry, 0.3 to 0.6 inch thick, with schist on both sides. The schist is a quartz-microcline-biotite schist with a little muscovite and rare grains of oligoclase. It has lenses of biotite and muscovite in which large scales of each mica lie at right angles to one another. The sheets of cavities in the quartz of the granite are about parallel to the course of the dikelet and the foliation of the schist. Two other sections of the schist show much apatite in minute crystals and rare particles of allanite. The sheets of cavities in the quartz particles of the schist are at right angles to its foliation and do not penetrate the quartz of the granite.

Although not connected with any quarry certain granite boulders on a shoulder of Miles Mountain, in Concord, in northeastern Vermont,[10] are of interest because of their inclusions of sedimentary schist still preserving bedding planes and cleavage foliation.

The general inferences from all these observations of inclusions are as follows:

Inclusions in granite rock may consist of any igneous or sedimentary rock intruded by the granite.

The ragged edges of schistose inclusions and the interbanding of granite with slivers of schist afford evidence of the lacerating effect of the intrusion upon such rocks.

The effect of heat upon the minerals of included metamorphic rocks was very slight indeed.

Inclusions in granite are likely to be associated with pegmatite and aplite.

The plastic granite in adapting itself to rigid inclusions of lower temperature usually rearranged its mineral constituents in zones about the inclusions, as in flow structure.

GNEISSIC STRUCTURE.

Gneissic structure consists of an alinement of the constituents of a granite in more or less parallel planes, giving to the rock a schis-

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[10] See Dale, T. N., U. S. Geol. Survey Bull. 589, p. 54, 1915.

tosity, as shown in Plate XXIX, *A*, so that it can be split into irregular, slablike pieces of minute or larger dimensions.

According to Gregory,[11] the sheets may be all of the same material or may be of different materials; for instance, sheets consisting largely of biotite and feldspar may alternate with sheets that are prevailingly quartz. Granite gneisses have been formed from granites, the change being chiefly a rearrangement of the mineral particles. The micas and other minerals are drawn out along well-marked planes, and new micas, both muscovite and biotite, have been produced. Gneiss may also contain tourmaline, garnet, and other minerals that are not generally found in granite. The difference in appearance between the granite and the gneiss will depend on the amount of metamorphism—chemical and crystalline action under moisture, heat, and compression—the rock has undergone. Occasionally the two types will appear in the same quarry, as in the Stony Creek region [Connecticut].

The general cause of gneissic structure is crustal compression.

RUSTY STAIN AND ITS CAUSES.

Rusty (limonite) staining ("sap") along the upper and lower parts of the sheets and also along the joints and headings is common in granite quarries, although some quarries are almost entirely free from it. The concentric inward growth of "sap" from the close joints of a heading is well shown in Plate XVII, *B*. The zone of stain along the sheets is from half an inch to 12 inches, exceptionally even 24 inches, wide on each side of the sheet parting. Its width, however, decreases gradually from the surface sheets downward. In places the "sap" consists of two parts—an outer dark brownish zone from 0.75 to 1.5 inches wide, and an inner more yellowish zone from 0.25 to 0.5 inch wide Generally, however, the stain diminishes gradually from without inward.

When the stone is intended for facing or trimming buildings the presence of "sap" is a serious matter, as the stained edge of each block must be split off, which adds somewhat to the cost of production. This stain has been supposed to be always due to the oxidation of the ferruginous minerals of the granite, biotite, hornblende, magnetite, and pyrite, but some thin sections do not bear out this theory.

Thus one from the Tayntor quarry, near Hallowell, Maine, shows that the stain has insinuated itself into the cleavage planes and cracks of the feldspar and muscovite and in the cracks of the quartz, forming minute deposits of limonite therein, but the biotite scales and magnetite particles are generally unrelated to the stain. A section, taken from the "top" of the Hopewell quarry, in Sullivan, Maine, where the fresh rock has a bluish tinge and the "sap" a general buff color, shows that the staining extends along the cleavages and fissures and in the spaces between the minerals, but that it does not appear in connection with the biotite scales, although it is increased by the magnetite particles. A section from the upper part of High Isle, south of Rockland, Maine, where the dark "sap" is 1 inch wide and an inner lighter part is 0.2 inch

[11] Gregory, H. E., U. S. Geol. Survey Bull. 484, pp. 16–17, 1911.

wide, shows a series of roughly parallel cracks crossing the "sap" vertically, with subsidiary transverse cracks. These cracks and the cleavages of the feldspar and the spaces between the minerals are stained, but the staining has no connection with the biotite, and some large particles of magnetite are scarcely touched by it. (See fig. 5.)

Limonitic stain is very abundant in the quarries at Rockport, Mass., where its brightness has led to the architectural use of the stone showing it. Thin sections of the Rockport "sap" show the stain along the boundaries of particles and in all cleavage and rift cracks as well as in streaks across them. It is conspicuous about hornblende and magnetite particles. The stain has also proceeded from the cracks inward into the intervening areas. The zonal arrangement of the stain is also noticeable. The medium gray of the fresh granite becomes at first greenish toward the surface; this is followed by a zone of deep yellow-brown; and that in turn by a much lighter yellow-brown. The greenish zone is that of advancing limonitization, the next of maximum stain, and the outside is that of delimonitization, or deoxidation due to organic acids, and made still lighter by the greater kaolinization of the feldspars of the surface. In some Rockport specimens this outer paler zone is covered by an extremely thin crust of bright yellow-brown, as if a secondary infiltration of limonite had taken place after the deoxidation. Although in the granite of Rockport the ferruginous minerals have furnished some of the stain, it is doubtful whether they could have supplied enough to color so many sheet and joint surfaces so intensely.

FIGURE 5.—Minerals in thin section (3.76 by 4.23 millimeters=0.15 by 0.17 inch) of biotite granite from High Isle in Knox County, Maine, showing "sap." The ramifications of "sap" (limonite stain) across and around feldspar and quartz particles (marked *f* and *q*) are independent of the biotite and magnetite particles. Fine-lined parts are biotite; fine-dotted areas are titanite; large black masses are magnetite. Some of the borders of quartz particles are shown by dotted lines.

A specimen of granite from the Dell Hitchcock quarry, Quincy, Mass., has a rim of "sap" from 1 to 1.5 inches wide, of which the inner tenth to three-tenths is dark brown and the rest light brown. The inner boundary is very uneven, the rusty part having encroached upon the granite in roundish protuberances. Some of the limonite streaks start from aegirite particles. In a piece from the Wigwam quarry the stain proceeds from magnetite particles and not from the

black silicates, but some of the magnetite particles are within crystals of riebeckite. In a specimen from the pea-green granite of the Lepage quarry, out of a rusty band 1.5 to 2 inches thick, an inner 0.2 inch is deep brown, but the fresh granite next to it is dark-greenish. The rest, or outer part, ranges from a very light brown to cream-colored at the surface. The stain proceeds from the black silicates and from the vicinity of zircon crystals, many of which are associated with iron in some form. An aegirite crystal is one-half hematite. The central parts of others are altered to limonite before the outer. A thin section of discolored granite from Westerly, R. I., also shows the rust stain arising from biotite and magnetite particles (p. 413).

In one of the fine-grained granites of Milford, N. H. (Hayden quarry, now abandoned), there are scattered porphyritic crystals of black mica up to 1 inch long, 0.5 inch wide, and very thin, around which, after exposure, a circle of slight limonitic stain 20 inches in diameter appears on the rift surface. The biotite probably contains, as usual, small particles of magnetite.

Another kind of limonitic staining, even more serious in its consequences, appears on fresh faces of granite, either in the quarry or after its removal. This consists of sporadic rusty stains from 0.5 to 1 inch in diameter, arising from the oxidation of minute particles of some undetermined ferruginous mineral, possibly allanite. Such stains generally, however, arise from pyrite.

Daly [12] describes a bluish-gray syenite from Windsor, Vt. (feldspar, quartz, hornblende, augite, biotite), that after 24 hours' exposure assumes a greenish tinge, which eventually becomes more or less brownish. He has demonstrated by experiment with oxygen that this change is due to the oxidation of minute blackish granules of ferrous oxide within the feldspar, giving a yellow which, in combination with the original bluish tint of the feldspar, produces a green. The large columns of the library of Columbia University, in New York, are made of this rock. The quartz diorite of Alfred, Maine (p. 272), becomes greenish after one or two years' exposure; and the gray hornblende granite of the Blood Ledge quarry, in Rockport, Mass. (p. 300), becomes olive-green in three or four hours after wetting.

Some of the green granites, as shown on page 76, owe much of their color to limonite stain proceeding from minute allanite crystals. (See fig. 6.)

Rusty discoloration in granite is thus of five kinds—that due to the infiltration of ferruginous water; that due to the oxidation of the generally disseminated ferruginous minerals (biotite, hornblende,

[12] Daly, R. A., The geology of Ascutney Mountain, Vermont: U. S. Geol. Survey Bull. 209, pp. 51–53, 1903.

aegirite, magnetite, and pyrite)[13] by nonferruginous water; that due to the oxidation of sporadic ferruginous minerals; that due to the oxidation of ferrous oxide within the feldspars; and finally that due to limonite from the alteration of the iron compounds in minute crystals of allanite. Of course, some rusty stain may have arisen from several of these sources combined.

The water that produces the rust-colored bands reaches the sheet partings through the intersecting joint partings and then travels between the sheets and permeates the lower surface of the overlying sheet and the upper surface of the underlying sheet by capillary attraction.

General Grant's tomb in New York is an unfortunate example of the discoloration of granite after its exposure to the weather. Neither the chemical analysis of the stone nor its appearance in the quarry or under the microscope affords any explanation of this change. (See under North Jay, Maine, pp. 212–214.) That the discoloration followed certain structural planes in the rock is evident, because the zones of stain are parallel to the axes of some of the columns but at right angles to those of others. It is also evident that some of the columns were cut parallel to the structure and others at right angles to it, a difference which makes the discoloration still more conspicuous. The only two structures are the rift, which is horizontal, and the flow structure, which is in gently inclined undulations. It may be surmised that in that portion of the quarry which furnished the stone for the tomb there was more iron in the form of pyrite or magnetite than there was in the samples of the stone the chemical, microscopic, and geologic study of which is here reported; and that upon continued exposure the oxidation of these iron compounds produced enough limonitic stain to discolor both walls and columns. This stain followed the arrangement of the pyrite and magnetic grains, which was probably in the direction of the flow structure.

Limonitic stain along the sheet surfaces may be removed by natural causes. At the Frazer quarry, on Blue Mountain, in Ryegate, Vt. (p. 115), there is a band of rusty stain along the base of a sheet 12 feet thick dipping 25° down the hill. The band, which is an inch wide, is separated from the lower surface of the sheet by 1 or 2 inches of clear granite. A careful examination of the specimen shows that all the minerals in the rusty band are stained a medium

[13] The rust-stained joint faces of aplite at Hingham, Mass. (p. 338), are probably due to the oxidation and hydration of its abundant pyrite as well as of its magnetite. Allen J. Howe (Geology of building stones, p. 360, London, 1910), states that "well-crystallized pyrite in a fresh granite is not a source of much danger, but it, like all other iron compounds, may produce, by oxidation and hydration, either local spots or a uniform tinge of iron stain, in accordance with its distribution in isolated crystals or in uniformly scattered granules."

brown, and that the space below it, although of the same color as that above it, yet has dots 0.1 inch wide of very dark brown. A thin section of this part shows limonite proceeding from biotite and allanite crystals. A thin section of the clear granite above the band shows no limonite whatever about a crystal of allanite. There seems, therefore, to have been a partial delimonitization of the lower part of the zone of "sap," which may be attributed to organic acids in the water circulating between the sheets after that which produced the stain.

At the old Crabtree quarry, east of Minturn, on Swans Island, in Maine, the limonitic band, about an inch thick, is 2 inches above the bottom of the sheet, owing to such delimonitization.

DECOMPOSITION.

GENERAL FEATURES.

Notwithstanding the strength and durability of granite, it is liable, under certain conditions and in the course of long time, to decompose into a clayey sand. This is the result of its physical, mineralogical, and chemical constitution and properties. One of the most striking illustrations of decomposition is the occurrence in some of the Maine quarries of "beds" of sand or decomposed granite within the fresh granite, either between the sheets away from headings or within the headings and along or across the sheets. Thus at the Palmer quarry, in Vinalhaven, 20 feet below the surface in the face of the quarry, there is a bed of granite sand 18 inches thick between two sheets, which at that point dip about 10° into the hill. On the southeast side of the Longfellow quarry, near Hallowell, some of the sheets within a wide heading include granite sand beds about 10 inches thick. At the Shattuck Mountain quarry, near Red Beach, a 6-foot heading includes a vertical layer of granite sand 8 inches thick. Specimens taken from these various sand beds show that the disintegration begins with microscopic fractures, or in some places the enlarged rift cracks, producing the "shake" structure described on page 39, and is followed by more or less kaolinization of the feldspars. This process consists in the loss of alkali and the taking up of water, resulting in the passing of the feldspar into a white clay (kaolin).

The joint and sheet structure affords ingress to surface water, which contains its usual percentage of carbonic acid, and the "rift" structure facilitates the kaolinization of the feldspar on either side of the sheet parting by this water. As the feldspars pass into clay the rock crumbles into sand consisting of quartz, mica, and kaolin and of feldspar in various stages of kaolinization. In some places within the range and depth of frost a large part of this work may

have been done by frost. The sand would there be mainly the product of the "shake" structure.

Along the Maine coast the surface of granite ledges bear in protected places an inch or so of granite sand, which represents surface disintegration since the postglacial submergence.

In regions that have not been swept by a continental glacier any granite mass would be covered with the products of the decomposition of its own surface. In the Tropics the abundant rainfall and the organic acids from a luxuriant vegetation materially hasten the decomposition, and granitic rocks in such regions are for these reasons often covered with many feet of sand and soil.[14]

Walther,[15] in an interesting work on erosion in the Egyptian desert, describes the effect of the weathering of a certain gray granite in the Sinaitic peninsula as the excavation of a series of circular holes, 1 to 8 inches in diameter and 4 to 20 inches deep, in the sides of the sheets. He attributes these holes to chemical action upon the feldspars in shady depressions where rain, dew, and rock moisture are less easily dried up, aided by the wind-blown sand of the desert. He also (p. 363) attributes exfoliation of granite in the desert, in which the folia measure 0.2–0.6 inch in thickness, to differences in temperature causing unequal expansion of the outer surface cooled at night and the inner one still preserving the heat of the previous day.

The incipient stage of weathering may be observed in any long-exposed granite ledge in the milky whiteness of the feldspars. This change usually attacks the soda-lime feldspars first. The black mica, owing to its content of iron oxide, is also liable to early decomposition. The process of weathering, as it affects the rock as a whole, involves the following chemical changes: A loss of lime, magnesia, potash, and soda; a gain of water, and a relative gain of silica, alumina, and iron oxide—that is, relative to the reduced weight of the weathered rock. The subject of weathering of granite is fully treated in the writings of Merrill,[16] Keyes,[17] and Watson.[18]

The changes in granite after it has entered into buildings or other structures are less marked than those in the natural rock, because the blocks are not then traversed by anything analogous to sheet and

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[14] Branner, J. C., Decomposition of rocks in Brazil: Geol. Soc. America Bull., vol. 7, p. 31, 1896.

[15] Walther, Johannes, Die Denüdation in der Wüste und ihre geologische Bedeutung: K. sächs. Gesell. Wiss., Math.-phys. Classe, Abh., vol. 16, pp. 367, 368, Leipzig, 1891.

[16] Merrill, G. P., Disintegration of the granite rocks of the District of Columbia: Geol. Soc. America Bull., vol. 6, p. 321, 1895; also A treatise on rocks, rock-weathering, and soils, pp. 206–214, 236, 244, 245, 257, New York, 1897.

[17] Keyes, C. R., The origin and relations of central Maryland granites: U. S. Geol Survey Fifteenth Ann. Rept., p. 725, pls. 42–45, 1895. See also Iowa Acad. Sci. Proc., vol. 1, pt. 3, pp. 22–24, vol. 2, pp. 27–31, pls. 2–4, 1895.

[18] Watson, T. L., A preliminary report on a part of the granites and gneisses of Georgia, pp. 299, 300, 308, 329, 331, 333, 1902.

joint structure, and also because the years of historic time are few compared to those of geologic time. Much has been written on the decay of granite in monuments and buildings.[19] Such decay is mainly attributable to microscopic fissures produced by the unequal and repeated expansion and contraction of the different minerals of the granite under changes of solar temperature. In countries where the winter temperature is very low the action of frost within such fissures powerfully assists the process of disintegration. Thus the obelisk now in New York suffered more from three years' exposure to our climate than it had during over 3,400 years in Egypt, although the fissures along which frost operated were started long before it reached this country. A minor factor in decay is the chemical action of water along fissures.[20]

The results of some recent studies on the weathering of ancient granite monuments in Egypt[21] show the durability of this stone in terms of years in that climate. It was found that in southern Egypt obelisks dating from 588 to 2100 B. C., or from 2,504 to 4,016 years old, showed no perceptible disintegration or even incipient exfoliation on southern exposures, but that farther north, at Luxor, Thebes, and Gizeh, and in the Museum at Cairo the granite (chiefly that of Syene) of pyramids, statues, and temples, dating from 318 to 2850 B. C., or from 2,234 to 4,766 years old, showed an average rate of disintegration and exfoliation ranging from nearly 0.04 to 0.08 inch per 1,000 years. The maximum rate in the temple at Karnak was about 0.2 inch per 1,000 years, and the minimum rate so slow as to be imperceptible in 3,000 years.

All the causes of decay referred to operate more effectively in coarse granites than in fine ones. Merrill points out that the reason for the greater resistance to weathering offered by sawn or polished surfaces than by cut or hammered surfaces is that the latter are full of minute fractures parallel to the surface, produced by tool impact, and that these fractures facilitate scaling.

OVOIDAL WEATHERING.

Shaler[22] called attention to spheroidal weathering in the granite of Rockport, and gave a plate showing "decomposition boulders," which are the result of the progress of decay working inward from

[19] Julien, A. A., The durability of building stones in New York City: Tenth Census, vol. 10, Granite, pp. 370–371, 1884. Merrill, Geo. P., Physical, chemical, and economic properties of building stones: Maryland Geol. Survey, vol. 2, Granite, pp. 92–94, 1898. Also Merrill's Stones for building and decoration, 3d ed., Weathering of granite, pp. 434, 435, 1903.

[20] Julien, A. A., A study of the New York obelisk as a decayed boulder: New York Acad. Sci. Annals, vol. 8, pp. 93–166, 1893.

[21] Barton, D. C., The disintegration of granite in Egypt: Jour. Geology, vol. 24, pp. 386–391, 1916.

[22] Shaler, N. S., The geology of Cape Ann, Mass.: U. S. Geol. Survey Ninth Ann. Rept., p. 567, pl. 51, 1889.

both sheet and joint surfaces. This is not unusual in granite regions. A fine illustration of the concentric surface weathering of granite in the Sierra Nevada was given by Turner.[23] This decay is mainly due to the chemical processes described under "Decomposition" (p. 70). Spheroidal weathering in granite may, however, be partly of different origin. The writer many years ago made some colored sketches of a concentric cylindrical structure in granite at a railroad cut at Unter Brambach, in Saxony, in which the surfaces an inch or two apart were coated with limonite stain. The cylindrical forms, although brought out by weathering, were apparently due to internal structure. Of like structural origin are also the concentric shelly spheroids of granite about an inner concretion of mica, a foot in diameter, in central Bohemia described by Jokély.[24]

P. A. Wagner[25] attributes spheroidal weathering in a South African granite to spheroidal contraction during cooling.

Plate XXIX, *B*, represents an ovoid mass of extremely fine quartz monzonite (45 by 33½ by 25 inches) from the Redstone quarry, near Westerly, R. I. (p. 413). This mass came from a point 30 feet below the surface within a heading 40 feet wide at the north end of the quarry, where much decomposition had taken place. As there are no indications at any of the Westerly quarries of an original spheroidal structure, this mass must be classed with those of Cape Ann, but the decomposition, instead of working on five sides of an exposed mass, has operated on the sides of a block formed by intersecting joints and sheets considerably below the general surface, and the egg shape is due to the unequal spacing of these partings.

SPECIAL FEATURES.

The following ten sections include certain geologic and petrographic features of granite which, although of scientific interest, hardly come under any of the previous headings.

PEGMATITE DIKES IN GROUPS.

The granite of Milford, N. H., is crossed by the usual pegmatite dikes, but at several quarries instead of being single or ramifying the dikes occur in parallel sets of 3 to 12 and have sinuous courses. This grouping is exceptional in the New England quarries. At the old Field quarry, near the village, the individual dikes measure 0.25 to 1 inch in width and number up to 10 in a set, and the sets recur at inter-

[23] Turner, H. W., Rocks of the Sierra Nevada: U. S. Geol. Survey Fourteenth Ann. Rept., pt. 2, p. 481, pl. 53, 1894.

[24] Jokély, Johann, Geognostische Verhältnisse in einem Theile des mittleren Böhmen: K.-k. geol. Reichsanstalt Jahrb., vol. 6, p. 375 and figure, 1855.

[25] Wagner, P. A., Negative spheroidal weathering and jointing in a granite of southern Rhodesia: Geol. Soc. South Africa Trans., vol. 15, pp. 155–164, pls. 18–21, 1913.

vals of 15 to 20 feet. At the abandoned Hayden quarry, a mile south, such dikes 0.25 to 1 inch wide and up to 12 in a group, recur at intervals of 20 to 30 feet. At the Young quarry, midway between these localities, the sets consist of 3 to 8 dikes up to 3 inches thick and recur at intervals of 20 feet. The dikes here meander and unite in the most intricate manner, occupying bands of granite 5 to 10 feet thick, which in quarrying have to be discarded. Somewhat similar dikes were noted in a small quarry 3 miles northeast of Lewiston, Maine, where a fine-grained biotite gneiss is traversed in a space of 30 feet by 27 pegmatite dikes, 1 inch to 2 feet thick, all dipping 80°.

It is difficult to explain the grouping and spacing of these dikes without supposing some periodicity in the application of the tension that made openings for them. The sinuosity of the courses of such dikes has been regarded as evidence that the openings were the result of tensile rather than of compressive or other strain.

MUSCOVITE VEINS.

At some of the quarries in Concord, N. H., the muscovite-biotite granite is traversed here and there by what quarrymen term "sand streaks" or "sand seams." These are veins of white mica, 0.1 to 0.4 inch wide, with a border of quartz and feldspar about 0.1 inch wide on each side. The mica plates measure up to 0.07 inch in diameter. Some of these veins, however, consist almost entirely of mica plates without any regular arrangement, attain a thickness of 1½ inches, and have mica plates up to 0.2 inch.

Veins of kindred but not identical character were observed at Milford, N. H. At the disused Field quarry muscovite veins 0.5 inch wide, with a central parting, recur at intervals of 15 to 20 feet. They strike like the pegmatite dikes referred to on page 73 and are discontinuous, not exceeding 6 feet at a stretch and being in places but a few inches. At the neighboring quarries of the Milford Granite Co. there is a heading striking N. 30° E., the joints of which inclose segregation veins of muscovite and quartz, the quartz in the center. These are from 0.1 to 0.5 inch wide and the granite is discolored bright reddish up to 0.5 inch on each side. The biotite is also chloritized.

It will be noticed that these Concord and Milford veins differ in that the former usually have muscovite in the center and the latter quartz. Both kinds of veins may be attributed to the percolation of mineral solutions along fissures. In either kind the outer mineral was deposited first. The proximity and parallelism of many of these veins to pegmatite dikes suggest that although deposited from solutions they were probably intimately related to the pegmatite dikes and were formed at the same time. In that case the heading referred to at Milford antedates the sheet structure.

ZEOLITE VEINS.

At the McGaughey quarry, in Mystic village, in Groton, Conn. (p. 388), the quartz monzonite has two zeolites. A vertical "blind seam," striking N. 60° E., proves to be a veinlet, 1 millimeter wide, of a fibrous light-brownish zeolite (natrolite?), with a more minute parallel branch, 0.5 millimeter away, of another zeolite near stilbite. This mineral has replaced some of the adjoining oligoclase-andesine and also sends microscopic veinlets across quartz particles. The granite is discolored for 0.5 inch on either side of the veinlet. A vertical pegmatite dike strikes N. 30° W.

MINERAL VEINS.

The presence of mineral veins in granite has no special significance in a work on granite, but in the one case noted the course of the vein was governed by that of a group of joints ("heading").

At the Roxbury quarry, Conn. (p. 372), owing to the proximity of a vein of siderite which was formerly mined, three veins, each not over 8 inches thick, consisting of siderite, pyrite, chalcopyrite, galena, and secondary quartz coating crystals of siderite, occur within and parallel to three vertical headings.

FELDSPARS.

ORIGINAL AND SECONDARY COLORS.

Although the shade of a granite is largely determined by that of its quartz particles and the relative abundance and size of its black mica scales, its general color is almost invariably determined by that of its feldspars. The colors of feldspars in commercial granite are so varied as to be an object of interest not only to the geologist but to the quarryman and the architect.

The New England granites described in this bulletin have feldspars of 11 colors—bluish, greenish, olive-green, pea-green, cream color, lavender, buff, pinkish buff, reddish, and greenish brown. Some are colorless and transparent or milk-white, others are dark or light gray, and the colored ones may be either transparent, translucent, or opaque. The relative opacity is determined mainly by degree of kaolinization and micacization.

In some granites the origin of the color is not easily determinable. Thus the feldspar of the granite of Concord, N. H., is translucent, with a slight bluish tinge, but the sections show no mineral which would produce such a tinge. In other granites, however, the results of microscopic examination are more satisfactory. Thus one of the granites of Rockport, Mass. (p. 298), owes its greenish tinge to chlorite scales and limonite stain. The granites of Milford, Mass.

(p. 342), have a delicate pink orthoclase and a yellow-greenish plagioclase. The greenish tint is due to innumerable minute crystals of epidote and a few scales of chlorite. The smallest of these epidote crystals measure about 0.001 millimeter. The orthoclase is much kaolinized, and the cause of the pinkish tinge is not apparent but is supposed to be due to the presence of infinitesimal particles of reddish hematite (Fe_2O_3).

The reddish biotite granite of the Redstone quarry at Westerly, R. I. (p. 412), contains a pinkish potash feldspar and a cream-colored plagioclase, both translucent and more or less micacized. They are both stained reddish here and there by hematite (Fe_2O_3) proceeding from the oxidation of magnetite particles (Fe_3O_4). This shows how the reddish color may be brought about. A similar reddening of the feldspar along the joint faces at Redstone, N. H., is due to hematite plainly proceeding from magnetite particles (p. 168).

The olive-green granite of Rockport (p. 293) contains a grayish olive-green orthoclase which appears crowded with opaque particles, the largest of which measure from 0.0028 to 0.014 millimeter. There is yellow limonitic ($Fe_4O_9H_6$) staining both along the rift cracks and about the opaque particles, some of which may be ferrous iron (FeO) and others kaolin. This limonite stain, in connection with an original bluish tinge unaccounted for, produces the olive-green. This granite contains also biotite and allanite. The similar olive-green granite from Redstone, N. H. (p. 168), owes its green tinge more to the color of the quartz than to that of the feldspar. The feldspar is a medium bluish gray with an occasional yellow-stained cleavage or rift crack. The limonite stain here clearly proceeds from the alteration of somewhat abundant particles and crystals of allanite,[26] as shown in figure 6, and also from particles of hornblende.

Daly[27] has shown experimentally that the green color which appears soon after exposure in the granite of Windsor, Vt., is due to the oxidization of extremely minute blackish granules of ferrous oxide in the feldspars and to the combination of the yellowish-brown color from the limonite thus produced with the bluish gray of the unaltered feldspar.

The bluish and greenish tints of the medium to dark gray feldspar of Quincy granite (p. 317) are due to finely disseminated crystals of bluish riebeckite, measuring from about 0.001 to 0.1 milli-

[26] See glossary (p. 467), also Iddings, J. P., and Cross, Whitman, On the widespread occurrence of allanite as an accessory constituent of many rocks: Am. Jour. Sci., 3d ser., vol. 30, pp. 108–111, 1885.

[27] Daly, R. A., The geology of Ascutney Mountain, Vt.: U. S. Geol. Survey Bull. 209, 1903.

meter in length by about 0.001 millimeter in width, and to innumerable still more minute particles of grass-green aegirite.

This bluish-greenish gray feldspar of Quincy granite assumes very different colors as the result of various alterations. In some places it becomes cream-colored, in others a delicate pea-green, or pink to pinkish gray or dark greenish-brownish gray, in others a light olive-gray, and in still others it becomes spotted with a deep red. The mode of these occurrences, the appearance of the changed feldspars in thin section, and probable causes of the changes are set forth below.

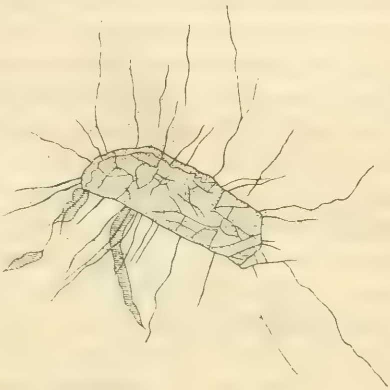

FIGURE 6. Part of a thin section of green biotite-hornblende granite from Redstone, Conway, N. H., enlarged 31⅓ diameters, showing a crystal of allanite with radiating cracks, which are filled with yellowish limonite stain, also bands of such stain apart from these cracks. The dotted areas are quartz, the rest feldspar. Such crystals in part account for the color of the rock.

At the Galvin quarry, in Quincy (p. 325), the granite on either side of the quartz veins, which contain a little ilmenite and carbonate, is changed for 4 inches from its usual bluish gray to cream-color. At the Field & Wild quarry, also in Quincy (p. 326), these veins are bordered by 3-inch zones of greenish, pinkish, or light-grayish discoloration. The cream and light gray seem to be due not so much to the kaolinization of the feldspars and to limonite stain from the ilmenite of the vein as to a diminution of certain minute black particles which abound in the unaltered feldspar. The pinkish color is due to hematite and the greenish to aegirite and the removal of the riebeckite. The reduction of the black particles and any kaolinization of the feldspars along these veins must be attributed to carbonic acid waters, and these must either have come from below with the silica of the vein or from above by infiltration along the vein courses.[28]

At the Cashman quarry, in West Quincy (p. 331), the granite at both the north and the south ends, to a depth of over 70 feet from the rock surface, has delicate pea-green feldspars, but normal gray granite occupies the center of the quarry. Similar pea-green feldspar occurs on the south side of the Lepage quarry (p. 330), in West Quincy, to a depth of 30 to 40 feet, and at one of the Winquist

[28] Van Hise, C. R., A treatise on metamorphism: U. S. Geol. Survey Mon. 47, pp. 720–728, 1904.

quarries on the North Commons (p. 324), to a depth of 125 feet from the rock surface. This pea-green tint seems to be due mainly to the presence of minute particles and crystals of light-green aegirite, and secondarily to the absence or removal of the minute riebeckite crystals. There is also here and there a secondary light yellowish-brown hornblende in minute prismatic crystals. This granite has the appearance of having undergone alteration of one or two kinds. Some structural feature seems necessary to account for the separation of two vertical belts of light-green granite by a normal gray one at the Cashman quarry.

A pink granite occupies one-half of the Savo quarry (p. 331), in West Quincy, to a depth of 30 feet, and the pea-green granite the other half. The feldspars of the pink stone have been kaolinized and made pink. The larger riebeckite and aegirite particles have passed into masses (pseudomorphs) of quartz, magnetite, and carbonate, with some epidote and chlorite. Magnetite crystals are conspicuous in them. The minute crystals of riebeckite have disappeared. These changes in the feldspar and the ferro-soda silicates could be explained by access of carbonated surface waters and metamorphic action. The color of the feldspar must be attributed either to the reduction of limonite particles or to the oxidation of magnetite.

At the Sartori quarry, in Quincy (p. 335), the feldspar has become largely kaolinized and micacized and also somewhat stained with hematite. It has lost its translucence and acquired a dull greenish-brown hue. The black silicates have passed largely into an aggregate of biotite, magnetite, carbonate, and quartz, and there are no minute riebeckite crystals in the feldspars.

At the Rogers quarry, in West Quincy (p. 333), the feldspars at the south end and west side become a light olive-gray after exposure. In thin section faint yellowish limonite stain appears along the rift and grain and along cleavage and irregular cracks. The yellow of the stain combined with the bluish green of the riebeckite yields an olive-gray. In one section bright limonite stain is seen to ramify from the large particles of intergrown riebeckite and aegirite.

At several Quincy quarries some of the granite is spotted with deep cherry-red and muddy olive-colored stains up to an inch in diameter. These stains surround the larger riebeckite and aegirite particles, from which they penetrate the adjacent feldspars. In thin section many of the feldspars are seen to be permeated by bright red hematite stain, ramifying within them from the cleavage and rift cracks, as shown in figure 7. This stain is also accompanied here and there by yellowish limonite stain probably of later date; and there are long, slender greenish particles up to 0.33 by 0.0002 millimeter, which are all parallel in the same feldspar crystal.

Radiating needle-like and fibrous felty crystals of secondary yellowish or muddy green hornblende are attached to the riebeckite and aegirite particles. Some of the aegirite crystals are completely altered to chlorite, magnetite, and quartz. The immediate cause of the staining of the feldspar and of the formation of the fibrous hornblende is thus the alteration of the riebeckite-aegirite particles, but the cause of that alteration is not so apparent. Their alteration to magnetite, alone, implies metamorphism. At the Cashman quarry, already referred to, some of this altered aegirite and feldspar was found next to a steep heading, and at the Hardwick quarry the granite within a heading has a hematitic color. These occurrences suggest that the change in the black silicates may have been brought about by access of surface water along joint planes, hydrating and oxidizing the iron of the silicates, and that the granite thus stained by limonite has become reddish as the limonite under metamorphism became reduced to hematite. It is also possible that, the black silicates having under metamorphism passed partly into magnetite, this may by oxidation have yielded hematite.

FIGURE 7.—Thin section of altered Quincy granite, enlarged 62½ diameters, showing hematite stain in the feldspar. The large particle from which streams of stain proceed is aegirite. Its altered parts are shaded.

This reddening of the feldspar also characterizes the gray granite of two of the quarries at Milford, N. H. (pp. 185, 187), for a thickness of 10 to 50 feet from its contact with basic dikes. The change takes place chiefly in the soda-lime feldspar, which is also much kaolinized. The source of this hematite is probably the magnetite particles.

CUT SURFACES.

In studying the "black granites" it was found that if one of two of identical shade is a diorite—that is, a granite with only a soda-lime feldspar—and the other a normal biotite granite—that is, a granite with very little soda-lime feldspar and considerable potash feldspar—the cut surface of the diorite will be very much lighter than that of the normal granite, and this was attributed to some optical property of the soda-lime feldspar. (See Pl. XXII, *A*.)

It has also been found that the pinkish and grayish quartz monzonites of Westerly, R. I., Milford, N. H., and Waterford and Groton, Conn., in which the soda-lime feldspar is in excess of the potash

feldspar, cut lighter than normal granites even of lighter tint. The very dark gabbros, syenites, diabases, and norites also cut light, as shown in Plates XXII, *B*, and VII, *B*. Dr. G. P. Merrill suggests that the optical property involved here is the multiple twinning of the soda-lime feldspar, which must greatly facilitate its breaking up under the hammer and thus increase the diffusion of light. As the dark purplish porphyritic rhyolite ("granite") of Montello, Wis., in which potash feldspar makes up half the rock and which has no other feldspar, hammers quite as light as the Westerly quartz monzonite, this shows that the same effect may be produced in some other way.[29]

GRANITIC QUARTZ.

TEXTURE.

The observations here brought together show that granitic quartz is far from possessing the homogeneous texture popularly attributed to that mineral. Not only is the quartz likely to contain cavities with or without vacuoles, as was shown on page 18, in intersecting sheets related to rift and grain cracks, but it also contains minute opaque particles, particularly abundant in smoky quartz. Some of it abounds in hairlike crystals, probably of rutile. The quartz of some granites shows by its behavior in polarized light that the arrangement of its molecules has been disturbed by mechanical strain. In three Massachusetts granites, Milford, Fall River, and Quincy Goldleaf quarry, and in that of Lebanon, N. H., this strain has been carried far enough to granulate the quartz. The granules generally measure under 1 millimeter in diameter.

COLORS.

The quartz of the granites described in this bulletin ranges from colorless, transparent or milky, to blue, amethystine smoky or milky, greenish smoky, rose-colored, and smoky of various shades. At Redstone, N. H. (p. 168), an amethystine smoky quartz has become greenish by the coating of its rift and grain cracks with limonite. Colorless quartz has the fewest cavities or particles. The smokiness appears to be due to minute black particles, but the microscope fails to show the cause of the blue, rose, and amethystine tints.[30]

The results of recent investigations by Watson and Beard[31] and those of previous writers quoted by them show that the amethyst

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[29] See Buckley, E. R., On the building and ornamental stones of Wisconsin: Wisconsin Geol. and Nat. Hist. Survey Bull. 4, p. 94, pl. 5, 1898.

[30] Rosenbusch, H., Mikroskopische Physiographie der Mineralien und Gesteine, 4th ed., vol. 1, pt. 2, Granit Quarz, pp. 93, 94, 1905.

[31] Watson, T. L., and Beard, R. E., The color of amethyst, rose, and blue varieties of quartz: U. S. Nat. Mus. Proc., vol. 53, pp. 553–563, 1917.

tint is due to manganese oxide, the rose tint to some organic substance, and the blue may be due to the reflection of blue light waves from abundant minute colorless prisms of rutile (titanium dioxide), whose width is a fraction of the length of light waves.

OLIVE-GREEN GRANITE.

The peculiar olive-green of the green granites of New England is due to changes both in the feldspar and the quartz as explained on page 76. The following description of a thin section of the green granite of Redstone, N. H. (p. 168), is typical of most of them.

There is a faint yellowish limonitic stain along the rift and grain cracks of the quartz, along these and the cleavage planes of the feldspar, and along borders of all particles. This stain is deeper in the quartz because there are more cracks in it, and this, in combination with its original slightly amethystine hue, gives the quartz a greenish tint; and this yellow stain also, in connection with the original slightly bluish gray of the feldspars, gives them in places a greenish color.

Olive-green granites occur also at Rockport (p. 293), Peabody (p. 287), and Lynnfield (p. 288), Mass.; at Kilkenny, N. H. (p. 176); and on Mount Ascutney, in Windsor, Vt. (p. 162). That of Rockport is a hornblende granite, that of Redstone a biotite-hornblende granite, that of Kilkenny an augite-biotite granite, and that of Windsor a hornblende-augite granite. The green granite of Peabody and Lynnfield (pp. 287–289) is also a hornblende-augite granite but contains less quartz and more dark silicates. It is analogous to the riebeckite-aegirite granite of Quincy, but its black silicates contain very little or no soda.

Washington [32] refers to this green granite in these words:

The rocks belonging to this class were first noticed by Wadsworth in 1885 and were later described more in detail by Sears. Rosenbusch has expressed the opinion that these are related to the akerite type of syenites, a keen observation which my study of the rocks fully confirms. These rocks are found chiefly in the eastern part of Essex County, in Essex, Beverly, Manchester, Gloucester, and on Cape Ann. * * * The color even of the freshest specimens is greenish, which varies in shade from a dark greenish black to a light shade of greenish gray.

In common with the green granites of Rockport and Redstone, that of Peabody and Lynnfield contains considerable allanite, to the oxidation of which the green color is partly due.

MINERALS ON JOINT FACES.

Many granite joint faces are coated with secondary minerals—hematite, pyrite, limonite, calcite, epidote, chlorite, stilbite, quartz,

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[32] Washington, H. S., The petrographical province of Essex County, Mass.: Jour. Geology, vol. 6, p. 787, 1898. See also Sears, J. H., The physical geography, geology, mineralogy, and paleontology of Essex County, Mass., pp. 178, 190, Salem, Mass., 1905.

and muscovite. All these may owe their origin to alteration of the minerals of the granite, but where calcite occurs in considerable quantity, as in the unusual and interesting granite found at the W. B. Blaisdell quarry, in Franklin, Maine, described under "Subjoints," on page 39, it very probably came from originally overlying calcareous rocks. But these may not have been those intruded by the granite.

Some of the joint and even sheet faces in the quarries at Quincy, Mass., are coated with a blue-black mineral with a peculiar sheen due to fibrous structure parallel to the face and with a bluish-gray streak. Such black faces can be seen at the Dell Hitchcock, Field & Wild, Granite Railway, and Rogers quarries and at the Mount Pleasant quarry in Milton. (See Pl. XXIV.) On one side of the Mount Pleasant quarry both sheet and joint faces are thus coated, and at the Rogers quarry such black joint faces, spaced from 6 inches to 4 feet, make up a heading. These black joints are commonly intermittent, however, extending only a few yards or even inches at a stretch.

A thin section cut diagonally to one of these joints and its parallel subjoints shows six meandering or intersecting cracks, 0.125 to 1.25 millimeters apart, filled with crystals of riebeckite (a dark-blue soda hornblende), the smallest of which are 0.02 and the largest 0.1 millimeter long, together with fibrous white mica, limonite, and very little carbonate. The granite between these fissures is broken up here and there into minute angular fragments and the feldspar is granulated. The cement of this microscopic breccia is also riebeckite, the crystals of which lie with their axes either parallel to the fracture or across them or even projecting into the feldspar fragments. Some of the feldspars next to the joint are unusually crowded with riebeckite crystals, which probably originated in the same manner and at the same time as those within the joints.[33]

The secondary and relatively recent origin of this riebeckite is evident, and its formation by segregation from the ferro-soda silicates of the granite seems also quite probable.

James P. Smith [34] has explained the alteration of a certain California arkose (decomposed granite or diorite) and a sandstone, with varying proportions of impure clay, into schists consisting largely of glaucophane (a soda hornblende closely related to riebeckite) as due to a process of recrystallization under heat and pressure.

At the Linehan quarry, in Peabody, Mass., the hornblende-augite granite has joints coated with hornblende and calcite.

In the riebeckite-coated joints and sheets of Quincy and the hornblende-coated joints of Peabody some transfer of material into the joint spaces must also have taken place. The presence of these minerals shows that the granite was subjected to a certain amount

[33] This and the occurrence of secondary riebeckite in rift and grain cracks, mentioned on p. 317, partly confirm the suspicion expressed by A. Sauer as to the origin of this mineral. See Deutsch. geol. Gesell. Zeitschr., vol. 40, p. 145, 1888.

[34] Smith, J. P., Paragenesis of the minerals in the glaucophane-bearing rocks of California: Am. Philos. Soc. Proc., vol. 45, p. 183, 1906. See also summary, idem, pp. 238, 240, 1906.

of metamorphism after the development of its sheet and joint structure.

Some joint faces at Milford and Becket, Mass., and Concord and Redstone, N. H., present different features. At the East quarry, Milford (p. 347), the parted joint which forms the west wall is filled with a fine-grained greenish, brownish, and cream-colored mass with transverse and longitudinal slickensided cracks. In thin section this proves to be a brecciated granite cemented with calcite, chlorite, fibrous muscovite, and limonite. The amount of calcite in this mass is so considerable that it seems improbable that the granite alone could have supplied it.

At the quarry of the Hudson & Chester Granite Co., in Becket (p. 280), some of the joint faces of the bluish-gray muscovite-biotite granite are dark greenish for 0.12 inch from the face. The granite in this zone has been altered by the formation of fibrous mica with limonite stain along cracks transverse to the face and along feldspar cleavages and by the formation of mica in the feldspars and of calcite both in the lime-soda feldspars and between the particles. These secondary minerals added to the original ones make these small rims very complex.

At the Upper or Granite Railway quarry of John Swenson, at Concord, N. H. (p. 200), joints with a N. 65° W. course and short parallel subjoints are coated with minute quartz crystals and obtuse calcite rhombs standing edgewise on the joint face, and also here and there with the beginnings of 2-inch cubes of deep purple and white fluorite. Similar fluorite occurs exceptionally within the granite near the face.

At Redstone, N. H. (p. 168), the light-pink granite for an inch back of one of the major joints is a yellowish pink with patches of grass-green, while the face itself is pale brick-red, rust-colored, bluish, and grass-green. Thin sections show the feldspars much altered to white micas and crossed by veinlets of them. They are also kaolinized and stained pink by hematite from the magnetite particles. There is some carbonate, limonite, chlorite, and epidote.

At the Sands quarry, in Vinalhaven, Maine, one of the joint faces bears very minute crystals of stilbite, a hydrous silicate of alumina, lime, and soda,[35] also hematite.

While nearly all the secondary minerals in these joint coatings (chlorite, epidote, muscovite, hematite, limonite, calcite, stilbite, and quartz) may be accounted for by processes of "deep-seated weathering"—that is, by the alteration, largely chemical, of the minerals of the granite itself—the fluorite was probably brought from the same source as the granite itself but at a later time, and the calcite from once overlying calcareous sedimentary beds.

[35] Determination by W. T. Schaller, of the United States Geological Survey.

Large areas of the joint faces in the Longfellow quarry, at Hallowell, Maine, are coated with dendrites (frostlike crystals) of iron oxides and probably maganese oxides from surface infiltration.

CONTACT PHENOMENA.

In the 425 granite quarries of New England contacts of the granite with the rock intruded by it were observed in the following townships and are mentioned in the quarry descriptions on the pages given: In Connecticut, in Groton (p. 386), East Lyme (p. 389), Mystic (p. 388), Seymour (p. 384), Stonington (p. 392), Thomaston (p. 373), and Waterford (Millstone and Waterford quarries, pp. 396, 398); in Maine, in Bristol (Round Pond, p. 249), Freeport (p. 211), and Waldoboro (p. 250, fig. 57); in Massachusetts, in Becket (p. 280) and North Acton (p. 308); in New Hampshire, in Manchester (p. 195) and

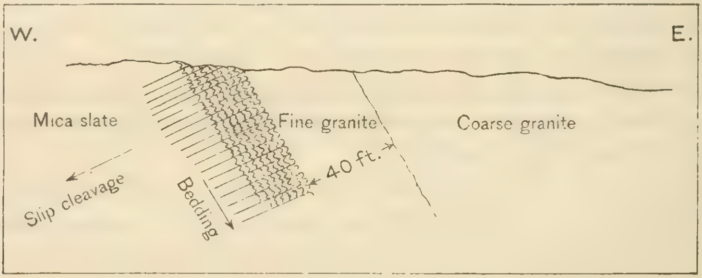

FIGURE 8.—Contact of quartz monzonite on the west side of Ellis quarry, Christian Hill, Bethel, Vt., showing relations of zone of fine granite to coarse granite and to bedding and cleavage of schist.

Milford (p. 180); in Rhode Island, in Charlestown (p. 415) and Westerly (p. 411); in Vermont, in Barre (p. 132), Bethel (p. 159), Hardwick (p. 120), and Plymouth (p. 160).

Out of all these contacts a few are of special petrographic or structural interest, and these will be described in some detail.

PETROGRAPHIC RELATIONS.

Bethel, Vt.—The white granite at Bethel, Vt. (p. 156), appears to be encircled by a zone of finer-grained light buff-gray granite, which is about 40 feet thick. Both rocks are quartz monzonites, but the finer contains more biotite scales than the coarser, and the scales are mostly very minute and evenly distributed. On the west side of the Ellis quarry the plane of contact between the coarse and the fine granite strikes N. 15° W. and dips 60° E. The fine-grained granite is in contact on the west with a finely plicated, very fine grained quartz-muscovite-biotite schist, and this granite is finer grained at its contact with the schist than it is 20 feet away. The plane of contact strikes and dips about like that between the two granites,

and the plications of the schist run parallel to this plane but are crossed by a slip cleavage striking N. 70° W. and dipping 25° WNW. The relations are shown in figure 8. Figure 9 shows how the granite has been molded by the minute wrinkles in the schist. The schist contains a few small garnets and plates of magnetite. In the glassy zone the particles range from 0.009 to 0.03 millimeter. In the next the porphyritic feldspars measure as high as 0.92 by 0.5 millimeter. There are thus four grades of texture in the granite—the glassy, 1 to 2 millimeters thick; the very fine (porphyritic, at least toward the

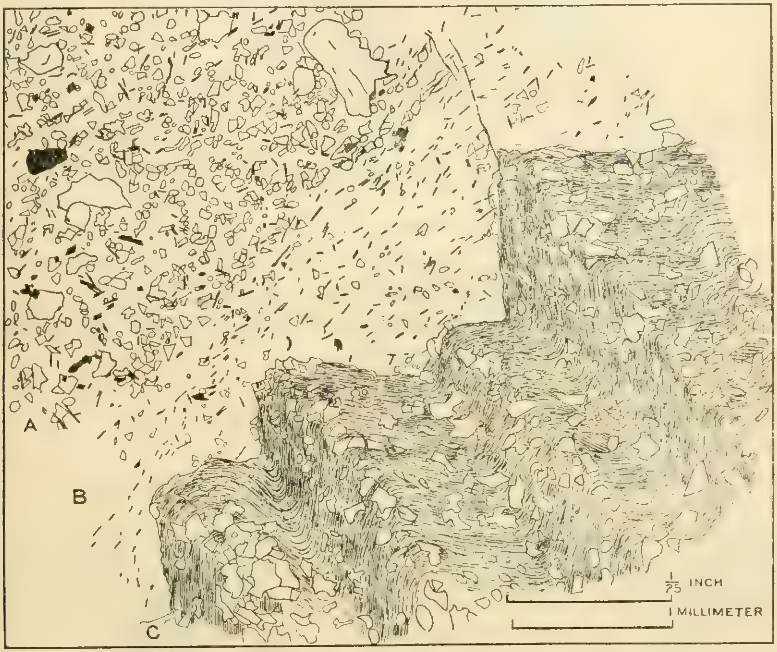

FIGURE 9.—Camera lucida drawing of enlarged thin section across contact of schist and granite at Bethel, Vt., shown in diagram in figure 8. A, Fine granite with some larger porphyritic feldspar and biotite scales. The finer undistinguishable particles of matrix are not shown. B, Zone, 1 to 2 millimeters wide, of glassy material with but few quartz and feldspar particles and biotite scales (in black); most of the latter with their long axis parallel to the general contact surface; a few at right angles to it. A fracture with limonite stain crosses this zone. C, Sharply plicated schist of fibrous muscovite with a little biotite and much quartz (unshaded particles). The two shaded particles are nonmetallic opaque mineral.

glassy), about 20 feet wide; the fine, with feldspar and mica not over 1 millimeter, about 20 feet wide; and the coarse, with feldspars up to 0.4 and 0.5 inch and mica to 0.3, over 200 feet wide.

Barre, Vt.—At the Anderson quarry, Barre, Vt. (No. 8, Pl. II, also p. 132), the granite contact with schist and slate is finely exposed. The under surface of the schist is coarsely serrate, forming as it were a series of folds, which, however, are not structural. The granite is

darker for a space of 25 feet from the schist, and a pegmatite dike, 1 foot thick, borders one of the schist tongues. (See fig. 10.)

In the southern corner of this quarry pieces of the mica slate have scaled off from the mass and been carried a few inches into the granite. (See fig. 11.) At this point the schist is a purplish-gray, very quartzose mica slate of quartz-feldspar-biotite, in places with muscovite also, in others without feldspar. Generally the rock resembles the mica slates used for whetstones. The slate has little dikes of pegmatite which start from the granite surface with a thickness of 0.5 inch and taper out at a distance of 4 feet. The course of these dikes has no reference to the cleavage of the slate, and their thickness is very irregular. The pegmatite consists, in descending order of abundance, of quartz, orthoclase, microcline, oligoclase-albite, and biotite. The quartz has cavities in sheets, some parallel to the dike, others across it. Minute particles of slate are here and there included in the pegmatite. The slate within a few inches of the granite is marked by very fine grained oval greenish-white spots, 0.1 to 0.5 inch and rarely 4 by 2 inches. These lenses lie with one of their major axes in the plane of the slaty cleavage. In some the biotite is zonally arranged, or the lens has a flange of biotite extending considerably beyond it and parallel to the slaty cleavage.

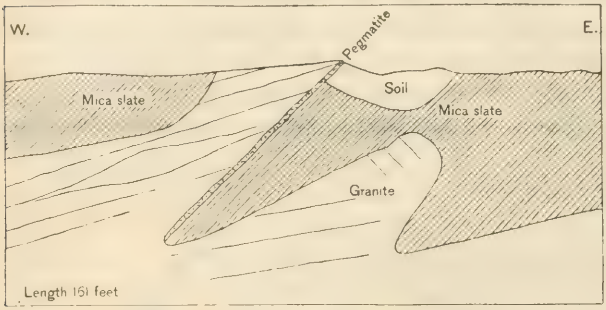

FIGURE 10.—Diagrammatic sketch showing relations of granite and mica schist and slate at Anderson quarry, Barre, Vt.

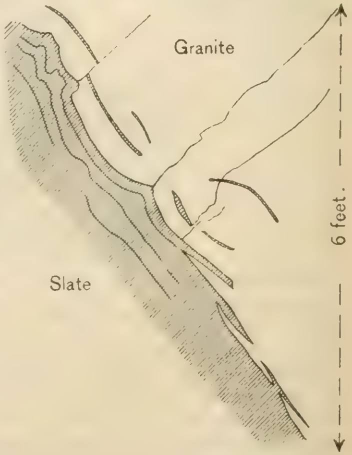

FIGURE 11.—Details at contact of mica slate and granite at south corner of Anderson quarry, Barre, Vt., as viewed along the strike of cleavage.

Small lenses (0.15 to 2.2 by 0.1 to 1 millimeter) were found in thin section to consist of granitic quartz with biotite and muscovite scales transverse or diagonal to the longer axis of the lens, and to be surrounded by a zone, 0.11 millimeter wide, of apatite particles. One has a little pyrite; another has apatite disseminated throughout it; another a little carbonate. The schist for a little space about the lens is finer grained than it is farther away. The little dikes do not show apatite except in rare, very minute prisms. Such dikes and lenses are shown in figure 12.

These lenses have usually been regarded as the result of vaporous impregnation from the granite along the cleavage foliation.[36] The slate about the lenses shows dark intersecting streaks which are due to more or less complete fractures lined with chlorite with a wide border of very minute undeterminable black particles.

At the Bailey quarry (No. 6, Pl. II) the contact is somewhat obscured by an inclusion which lies very near the schist capping. The schist, which is like that of the large inclusion at the Boutwell quarry, described on page 64, consists of little beds of whitish quartzite dotted with greenish hornblende and a few garnets, alternating

FIGURE 12.—Specimen of purplish-gray mica slate with minute dikes of pegmatite and lenses of apatitic granite, obtained near contact with granite at Anderson quarry, Barre, Vt. Cleavage parallel to length of block. At bottom several lenses (enlarged one half) from other side of same specimen, showing biotite flanges and relation to cleavage.

with little beds of quartz-biotite schist spangled with biotite scales. These beds are crossed by large and minute dikes of pegmatite. Some of them, only 0.3 to 0.4 inch wide, run transverse to the bedding for a space and then subdivide to pass at right angles within one of the little beds. Small hand specimens combining both transverse and longitudinal dike courses can be obtained here. The aplite here has a matrix of quartz, oligoclase-albite, microcline, in particles measur-

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[36] Vogt regards apatite in veins as having been formed by pneumatolytic agencies. Vogt, J. H. L., Ueber die durch pneumatolitische Processe an Granitgebundenen Mineralneubildungen: Zeitschr. prakt. Geologie, 1894, p. 458; Die Apatit-Ganggruppe: Idem, 1895, pp. 367, 444, 465. Barrell describes the occurrence of apatite in a banded hornstone at contact with granite. He attributes this apatitization to pneumatolytic impregnation. See Barrell, Joseph, Geology of the Marysville mining district, Mont.: U. S. Geol. Survey Prof. Paper 57, pp. 128, 130, 1907. For the formation of apatite at contact of diabase and granite, see p. 54 of this bulletin.

ing 0.25 to 0.1 millimeter, with porphyritic feldspar and quartz measuring from 0.25 to 1 millimeter.

Woodbury, Vt.—The contact of granite and schist is finely exposed on the northwest side of Robeson Mountain, Woodbury, Vt., along the granite railroad. The axes of the schist folds strike N. 70° W. and pitch 30° S.; the axis of the hill runs about N. 70° E. The plane of contact appears to be about parallel to the strike. The schist is of two sorts. One is a dark, rather coarse biotite-muscovite-quartz schist with minute black particles and speckled with lenticular biotite plates (up to 0.75 by 0.25 millimeter) lying across the schistosity of the rock. Some plates have a nucleus of magnetite. There are also a few lenses of pyrite. The other sort, a thin bed of which touches the granite, is a dark bluish-gray calcareous muscovitic quartzite with abundant slender flattish six-sided prisms (up to 2 by 0.34 millimeters) of a light-colored amphibole. These are evidently the product of contact metamorphism. The granite sends little pegmatitic dikes into the schist. At the Webber quarry, north of the mountain, the capping is similarly injected.

Conclusions.—All these contact phenomena lead to the following general inferences:

The 40-foot zone of fine-grained granite, with its three grades of texture, which intervenes between the coarse granite and the schist at Bethel, shows the effect of more rapid cooling upon texture. The material nearest the schist is glassy, but that farthest away is coarsely crystalline. The semiliquid condition of the granite when it met the schist is shown by its having been molded by the delicate plications of the schist.

That the granite intrusion at Barre was accomplished under great pressure is indicated by the intrusion of minute granitic dikes into such narrow transverse and longitudinal fissures in the schist and slate.

That the granitic intrusion at Barre was also attended by sufficient heat and moisture to inject quartz, feldspar, biotite, pyrite, and apatite (constituents of granite) in vaporous condition into the cleavage foliation of the slate is shown by the position and character of the lenses described. The formation of these lenses also affected the texture of the slate.

At Woodbury the same causes sufficed to produce minute amphibole prisms within a calcareous quartzite along the granite contact.

The phenomena at these contacts of granite with slate and schist, although on so small a scale, are scientifically related to the famous Sea Point locality in South Africa, about which at least 10 geologists

have written from 1813 to 1914.[37] The granite there not only sends out large and small dikes of both coarse and fine granite into the slate, but the slate has become impregnated with feldspar forming crystals up to 2 inches in length. In places the slate has been metamorphosed into a gneiss; both small and large pieces of slate have also been incorporated in the granite; and in places the rock is a complete mixture of slate and granite.

STRUCTURAL RELATIONS.

Waterford, Conn.—At the Millstone quarry, Waterford, Conn. (p. 396), the granite is capped on the northeast wall by several masses of gneiss up to 25 feet thick with a foliation striking N. 70° W. and dipping 25° N. 20° E. At the shore south of the quarry the same gneiss strikes N. 85° E. and dips steeply north, with pegmatite dikes 2 to 3 feet thick. The plane of contact between the granite and the gneiss remnants is in some places vertical, in others horizontal or gently inclined, the original complete outline of that plane having evidently been very irregular. In the central embayment, 15 to 20 feet of granite overlies a sagging strip of the gneiss 5 to 10 feet thick. Large dikes of pegmatite, starting at the contact, penetrate the gneiss, and in places the gneiss is cut up by an intricate network of pegmatite and aplite dikes. One of these pegmatite dikes contains a fragment of the gneiss 5 feet long, in vertical position. (See fig. 90.)

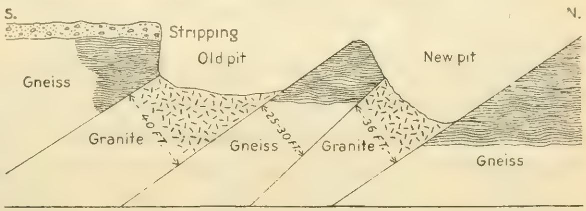

FIGURE 13.—Section of Waterford quarry, Waterford, Conn. Total length, 265 feet.

At the Waterford quarry (p. 398) the granite occurs in two dike-like masses, 30 and 40 feet thick, alternating with three masses of granite gneiss, the central one of which is 20 to 30 feet thick, all striking N. 80° E. and dipping 30°–45° S. 10° E. The relations are shown in figure 13. The gneiss foliation strikes N. 45°–60° W. and dips about 40° NE. but in places is nearly horizontal. The two granite masses are apparently connected in the center of the quarry by a small dike of the granite crossing the gneiss mass, as shown in figure

[37] Some of the more important of these papers are:

Darwin, Charles, Observations on the volcanic islands visited during the voyage of H. M. S. *Beagle*, together with some brief notices on the geology of Australia and the Cape of Good Hope, pp. 148–152, London, 1844.

Cohen, E., Geognostische-petrographische Skizzen aus Süd Africa: Neues Jahrb., 1874, pp. 477–503.

Hatch, F. H., and Corstorphine, G. S., Geology of South Africa, pp. 36–41, London, 1905.

Schwarz, E. H. L., The Sea Point granite-slate contact: Geol. Soc. South Africa Trans., vol. 16, pp. 33–38, 1914.

14. This gneiss (specimen D, XXX, 5, c, Mamacoke gneiss, No. 36 of the State preliminary geologic map) is a black and white banded fine-grained quartz monzonite gneiss, consisting, in descending order of abundance, of light smoky quartz, milk-white oligoclase, very little microcline, and biotite. The granite sheets, 1 to 9 feet thick, are lenticular, irregular, dipping south and southeast at 15°–22°. The sheet structure of the gneiss is not continuous with that of the granite, as shown in figures 14 and 15, evidently having been set up before the intrusion of the granite.

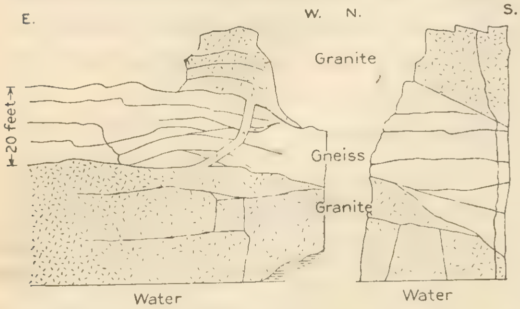

Figure 14.—Relations of granite and granite gneiss in center of Waterford quarry, Waterford, Conn.

Waldoboro, Maine.—At the Waldoboro quarry, Waldoboro, Maine, the original contact of the upper part of the granite mass with the lower part of the remnant of the schist mass, which once overlay that region and into which the granite was intruded, is exposed. (See Pl. XVII, *A*, and p. 250.) This schist is an amphibole-biotite-quartz schist containing some andesine feldspar, also accessory titanite and zircon. It is a metamorphosed rock, probably of sedimentary origin. At the opposite or southwest end of the quarry (see fig. 16) the relations between the schist and granite are very complex, and in places a considerable mass of pegmatite intervenes. The granite sends small dikes into the schist and also contains inclusions of it. The granite was erupted after or during the folding of the schist, otherwise it would have become a gneiss.

Milford, N. H.—At the southwest corner of the Pease quarry, at Milford, N. H. (p. 185), mica diorite gneiss, about 6 feet thick, overlies the fine-grained quartz monzonite, as shown in figure 17, with a foliation striking N. 75° W. and a dip of 20° S. The granite has a flow structure about parallel to the contact surface, but sheet structure crosses both gneiss and granite and flow structure and postdates them all.

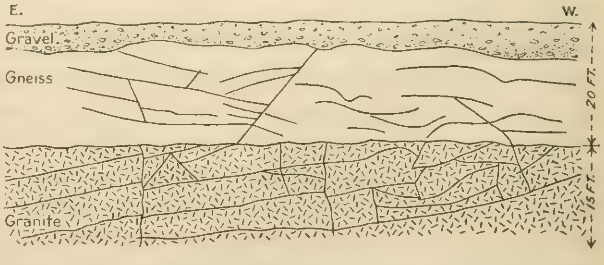

Figure 15.—Discordant sheet structure in granite and granite gneiss on south wall of Waterford quarry, Waterford, Conn.

At the quarries of the Milford Granite Co., now idle (p. 189), there is a working face on the west about 1,000 feet long. At its south and north ends granite and gneiss contacts are finely exposed. The fine-grained quartz monzonite is overlain by about 15 feet of gneiss, with a foliation striking N. 75° W. and dipping 75° SW. Plate VIII, *A*, shows the contact at the north end of the cut. The sheet structure is lenticular horizontal but does not continue into the gneiss, which seems to have an independent and discontinuous sheet structure of its own. The gneiss varies greatly in texture, composition, and color. In some places it is coarse, black, biotitic, and hornblendic; in others medium grained, gray or white, and more quartzose and feldspathic. It appears to be a quartz-mica diorite gneiss but contains streaks of a finely banded light-greenish fine-grained rock, which in thin section shows quartz, soda-lime feldspar (oligoclase-andesine), augite, hornblende, and biotite and thus appears to be a quartz-augite diorite gneiss. There are also dikes of pegmatite starting from the surface of the granite and tapering out in the gneiss.

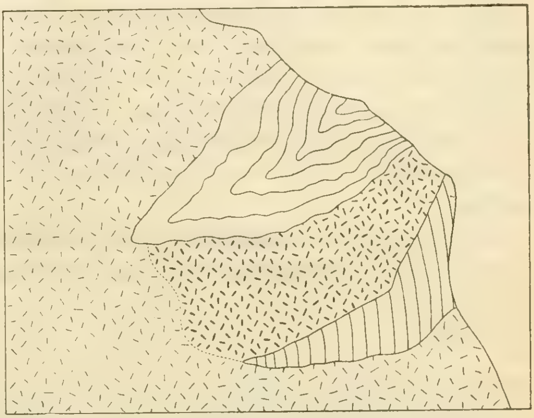

FIGURE 16.—Schist at southwest end of Waldoboro quarry, Waldoboro, Maine. Total height, 45 feet. The coarse material, between the two inclusions, is pegmatite. The finer is muscovite-biotite granite.

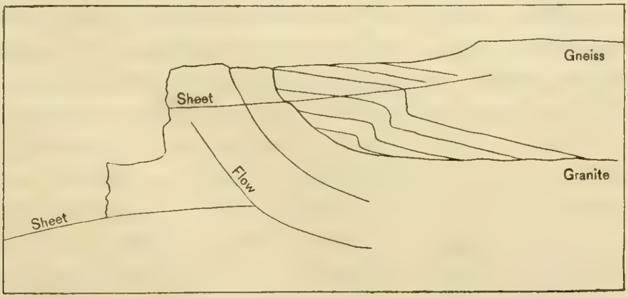

FIGURE 17.—Section showing relations of granite and gneiss at the Pease quarry, near Milford, N. H.; height, 10 feet. The flow structure is parallel to the contact surface, and sheet structure traverses both rocks.

Westerly and Charlestown, R. I.—At the Catto quarry in Westerly, R. I. (p. 412), the granite is a quartz monzonite. The sheets, from 6 inches to 10 feet thick, dip north at low angle. The east face of the quarry shows the relations of the granite to overlying granite

gneiss. (See fig. 18.) This strip of gneiss extends the entire width of the quarry, with a foliation striking N. 65° W. and dipping 65° NNW. As the granite crops out in places above the gneiss, this may be a very large inclusion, but it probably came from immediately under the original capping. The gneiss is so broken up here that hand specimens, half granite and half gneiss, with granite cutting the gneiss foliation, can be readily obtained. The gneiss is rather fine grained and consists of dark-gray very biotitic bands, 0.1 to 0.3 inch wide, alternating with light-gray bands that contain little biotite and with very light bands in which biotite is altogether lacking.

At the Klondike quarry (p. 415), in Charlestown, near Bradford Station, R. I., the fine-grained quartz monzonite is overlain on the west side by 50 feet of medium-grained biotite gneiss with porphyritic lenticular potash feldspars (microcline) up to 1.5 inches long, most of them rimmed with white soda-lime feldspar (oligoclase - andesine). The foliation of this gneiss is about horizontal. As shown in Plate XXXIV, *A*, the contact between the granite and gneiss dips somewhat steeply, and sheet structure crosses both granite and gneiss at a lesser angle. There are also dikes of pegmatite beginning at the contact and tapering upward in the gneiss. On the east side the same gneiss underlies the granite, the granite intrusion having apparently reached the present surface in a dikelike mass, the sides of which dipped about 30° S. and cut a mass of porphyritic biotite granite gneiss. The granite mass is about 75 feet thick, measured at right angles to its inclination. The foliation of the gneiss is not far from horizontal. On the south side the sheet structure extends into the gneiss, as shown in Plate XXXIV, *A*, and figure 93 (p. 416). Fifteen feet below the gneiss the granite contains one or more angular inclusions of finely banded biotite gneiss. Three years after the writer's visit the excavation showed the quartz monzonite dike narrowing downward, so that the figure requires some modification.

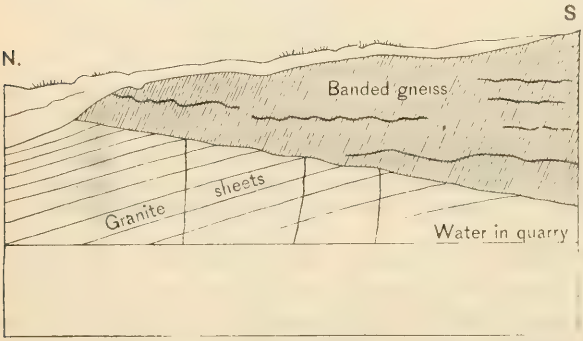

FIGURE 18.—Diagram of east face of Catto quarry, Westerly, R. I., showing granite overlain by a mass of biotite granite gneiss, each with its own sheet structure, also vertical joints in the granite. Length, 65 feet; height above quarry water, 50 feet.

Conclusions.—These structural contact phenomena lead to the following inferences:

Flow structure in places is parallel to the under surface of the intruded rock.

Sheet structure is quite independent of flow structure.

In some places sheet structure was set up in the granite gneiss of the capping prior to the granitic intrusion, but in others (Pease quarry, Milford, N. H.; Klondike quarry, Charlestown, R. I.) the sheet structure of the granite passes into the intruded gneiss and is of later date than the intrusion itself.

The contact surface in places is rudely serrate or otherwise irregular from the ruptures caused by the intrusion, and large fragments of the intruded rock evidently dropped into the plastic granite.

The intrusion of a granite gneiss by a gneissoid granite indicates two periods of intrusion and two of metamorphism at the same locality.

The thinness of the schist or gneiss (in places only 25 feet) now capping the granite indicates the erosion of at least several hundred feet of the capping since the intrusion took place. (See p. 4.)

Pegmatite and aplite dikes usually originate at the surface of the intruding granite and penetrate the intruded mass. Pegmatite also collects along the intruded surface and about the inclusions.

PLICATED GNEISSIC TEXTURE.

Under metamorphism a granite passes into a granite gneiss (p. 65)—that is, from a massive crystalline to a schistose condition. If this schistose granite is subjected to lateral compression its foliation will become plicated, and if the pressure continues the plications may even be faulted. An interesting example of this is seen at the West quarry, on Hoadly Neck, in Branford, Conn. (p. 381), and is shown in figure 19. The original granite was very coarsely porphyritic, and the feldspars have become lenses up to 3 inches in length. The little folds are up to 10 inches in width and are faulted.

"BLACK GRANITES."

CLASSIFICATION.

The term "black granites," although sufficiently descriptive for general commercial purposes, includes a variety of rocks of different character, origin, and appearance—gabbros, diorites, diabase, etc. They have, however, three mineralogic features in common—they contain comparatively little or no quartz, their feldspar belongs entirely or almost entirely to the series which contains both soda and lime, and they contain a considerable amount of one of the pyroxenes, or hornblende or biotite, and magnetite, which accounts for the general darkness of their shade or their greenish color.

ORIGIN.

The gabbros and diorites are more or less granitic in texture, as they crystallized under conditions resembling those which attended the formation of granite. But the diabase was in part erupted through narrow fissures, forming dikes or sheets, and at many places reached the surface, always crystallizing with comparative rapidity.

Diabase, however, occurs in Vinalhaven, Maine, as stated by George Otis Smith, " in large bodies which have the form of neither dikes

FIGURE 19.—Lower: Block of plicated biotite granite gneiss from West quarry, Hoadly Point, Branford, Conn. Upper: Plicated and faulted band of fine biotite granite gneiss within the coarser gneiss of same quarry. Hammers 20 inches long. (From photographs.)

nor sheets, being, in fact, part of the same masses as the diorites and gabbros."

MINERAL AND CHEMICAL COMPOSITION.

Gabbro consists essentially of a lime-soda feldspar and one or both of the varieties of pyroxene known as diallage and hypersthene. Diallage is a foliated silicate of iron and lime with about 12 per cent of magnesia; hypersthene is a silicate of iron with about 24 per cent of magnesia. Each of these minerals crystallizes differently. Rock that contains hypersthene is called a norite; rock that contains both hypersthene and diallage is a hypersthene gabbro. If the mineral olivine (a greenish silicate of iron with 50 per cent of mag-

nesia) is present also the name olivine may be prefixed to the rock name. The accessory minerals in gabbros are ilmenite (a titanate of iron), magnetite, pyrite, apatite, biotite, garnet, and rarely quartz and metallic iron. The secondary minerals—that is, those derived from the alteration of the primary ones—are hornblende, chlorite, epidote, zoisite, analcite, serpentine, a white mica, and calcite. The percentage of silica in gabbros varies a little on each side of 50. Iron oxides and lime average 9 per cent each; magnesia, 6 per cent.

Diorite consists essentially of feldspar (of the series containing lime and soda) and hornblende with biotite, or biotite alone. Quartz, augite, and potash feldspar may or may not be present. The accessory minerals are magnetite, pyrite, titanite, zircon, apatite, garnet, and allanite. The secondary minerals are epidote, chlorite, a white mica, and calcite. If quartz is present the rock is called a quartz diorite. If black mica or augite are the preponderating iron-magnesium silicates the rock is a mica diorite or an augite diorite. In diorites the silica ranges from about 49 to 63 per cent, but in quartz diorite it rises to about 69 per cent, which is the minimum in granite. The iron oxides range from 0.52 to 9.70 per cent, the magnesia from less than 1 to more than 11 per cent, but usually from 2 to 7 per cent.

Diabase consists essentially of a feldspar of the series containing lime, or soda and lime, together with a pyroxene (usually augite, a silicate of alumina, lime, magnesia, and iron), which, however, is frequently altered to hornblende or other secondary minerals; also magnetite or ilmenite, or both. Olivine may or may not be present, and some specimens contain a little quartz. The accessory minerals are orthoclase, biotite, pyrite, hypersthene, and apatite. The secondary minerals are hornblende, a white mica, chlorite, epidote, serpentine, and calcite. The percentage of silica in diabase ranges from about 45 to nearly 57, of iron oxides from about 9 to 14, and of magnesia from 3 to 9.

These "black granites," as will be seen by the foregoing descriptions, are distinguished chemically from the ordinary granites by their low percentage of silica (45 to 67 per cent), their high maxima of iron oxides (9 to 14 per cent) and of magnesia (9 to 11 per cent), and mineralogically by their dominant feldspar not being a potash feldspar, and generally also by their considerable content of the darker iron-magnesia minerals.

TEXTURE.

The general texture of the "black granites" corresponds in grade to that of the fine and medium granites. In the diorites the arrangement and order of crystallization of the minerals always correspond to those of the granites described on page 10. In some of the gabbros

this is also true, but in others and in diabase the arrangement greatly differs. The feldspars are in needle-like crystals, between which the pyroxene has afterward crystallized (ophitic texture).

PHYSICAL PROPERTIES.

Aside from their great toughness, the diorites and the granitic gabbros probably differ but little in physical properties from granites of the same grade of texture. By reason both of their peculiar texture and their mineral composition, the diabases and gabbros with ophitic texture should differ considerably in physical properties from the granites. As these stones are rarely used in large buildings, owing to the difficulty of quarrying them either in blocks of sufficient size or at low enough cost, data as to their compressive strength and other useful physical properties are not available.

The specific gravity of gabbro ranges from 2.66 to about 3, that of diabase from 2.7 to 2.98, and that of diorite averages 2.95. In these rocks it thus usually exceeds that of granite.

As the "black granites" are used chiefly for monumental purposes, and particularly for inscriptions, their color, susceptibilty to polish, and the amount of contrast between their cut or hammered and their polished surfaces are the physical properties of chief economic importance.

Merrill[28] explains the cause of these contrasts very satisfactorily:

> The impact of the hammer breaks up the granules on the immediate surface, so that the light falling upon it is reflected instead of absorbed, and the resultant effect upon the eye is that of whiteness. The darker color of a polished surface is due merely to the fact that, through careful grinding, all these irregularities and reflecting surfaces are removed, the light penetrating the stone is absorbed, and the effect upon the eye is that of a more or less complete absence of light, or darkness. Obviously, then, the more transparent the feldspars and the greater the abundance of dark minerals, the greater will be the contrast between hammered and polished surfaces. This is a matter worthy of consideration in cases where it is wished, as in a monument, to have a polished die surrounded by a margin of hammered work to give contrast.

The ordinary granites, while taking a high polish, do not afford such strong contrasts between hammered and polished surfaces as the "black granites." In some black granites this seems clearly to be due to their larger percentage of the black minerals, but in others, as some of the quartz diorites, in which the black minerals do not exceed those in some gray granites, the cause of this marked contrast must be sought in some optical property of the soda-lime feldspar and in its relative abundance.

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[28] Merrill, G. P., The physical, chemical, and economic properties of building stones: Maryland Geol. Survey, vol. 2, p. 64, 1898.

TEXT-BOOK REFERENCES ON GRANITE AND "BLACK GRANITES."

As the matter contained in the foregoing pages may not fully provide answers to all questions arising in the minds of persons interested in tracing the phenomena in granite quarries to their causes, the names of a few reliable general works in English on the subjects considered are here given.

DANA, J. D., Manual of mineralogy, 13th ed., by W. E. Ford, New York, 1912.

DANA, E. S., Textbook of mineralogy (with treatise on crystallography).

GEIKIE, ARCHIBALD, Textbook of geology, 4th ed., London, 1903.
Granite, etc., pp. 89, 90, 203–209, 402–415, 715–809; gabbro, pp. 231, 232, 256; diorite, p. 223; diabase, p. 233; basalt, p. 234.

HARKER, ALFRED, Petrography for students; an introduction to the study of rocks under the microscope, 4th ed., Cambridge, England, 1908.
Granites, pp. 27–41; gabbros, pp. 67–83; diorite, pp. 54–66; basalts, pp. 188–203.

HATCH, F. H., The petrology of the igneous rocks, 7th ed., London, 1915.

JOHANNSEN, ALBERT, Essentials for the microscopical determination of rock-forming minerals and rocks, Chicago, 1922.

KEMP, J. F., A handbook of rocks for use without the microscope, 3d ed., New York, 1904.
The granites, pp. 33–38; gabbros, pp. 72–74; diorites, pp. 60–62; diabases, pp. 70–72.

LUQUER, L. M., Minerals in rock sections, revised ed., New York, 1908.

MERRILL, G. P., A treatise on rocks, rock weathering, and soils, 2d ed., New York, 1906.
Igneous rocks, pp. 52–60; granites, pp. 61–64; diorites, pp. 76–77; diabases, pp. 82, 85; basalts, pp. 86, 87; weathering, pp. 150–273.

PIRSSON, L. V., Rocks and rock minerals; a manual of the elements of petrology without the use of the microscope, New York, 1908.

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PART II.—ECONOMIC DISCUSSION.

GENERAL FEATURES.

The practical side of the granite industry will now be considered. A list of the more important works on granite quarries and quarrying and other matters of economic character will be found at the end, together with a glossary of both scientific and quarry terms.

TESTS OF GRANITE.

The testing of granite is a subject of considerable importance, as may be seen by its literature given on pages 464–467. As pointed out by Merrill, there is danger of attaching undue importance to tests of compressive strength alone, the results of which almost invariably far exceed the generous margin allowed by architects beyond that required by the weightiest structures. On the other hand, there is danger of losing sight of several other qualities which ought to be carefully tested and upon which the economic value of granite in part depends. The following tests include all the kinds made at European testing institutions or recommended by American authorities, as well as some suggested by the writer's investigation of New England granites:

Chemical analysis.—Chemical analysis is made in order to determine the amount of iron and lime or to detect anything abnormal in the composition.

Determination of $CaCO_3$.—Tests are made to determine the presence of lime not combined with silicates in order to ascertain the percentage of $CaCO_3$ (lime carbonate) present. This is done by powdering and treatment with warm dilute acetic acid.

Test for discoloration.—The method applied by Daly [1] seems to be well adapted for the test for discoloration. A piece of fresh rock is immersed in a stream of carbon dioxide gas for 20 minutes and then kept in an atmosphere of that gas for 24 hours. Another piece of fresh rock is placed in an atmosphere of purified oxygen overnight and then exposed for 30 minutes to a temperature of 150° C. (302° F.). Any discoloration due to the carbonization or oxidation of the minutest particles of any mineral would be sure to show itself under these tests.

Mineral composition.—The mineral composition is determined by the microscopic examination of a considerable number of typical

[1] U. S. Geol. Survey Bull. 209, p. 52, 1903.

thin sections. All the mineral constituents are noted, and for the fine-textured granites the average size of the mineral particles is estimated. Any peculiarities of texture, rift, etc., can also be noted.

Proportions of minerals.—The method devised by Rosiwal,[39] of the Austrian Geological Survey, by which the approximate proportions of the chief minerals (feldspar, quartz, mica, hornblende) and their average size can be determined, consists in tracing a network of lines intersecting one another at right angles upon a polished granite surface, at intervals so great that no two parallel lines will traverse the same mineral particle. The total length of the lines is measured, then the diameters of all the particles of each kind of mineral are added separately and their proportion to the total length of the lines obtained. The average size of the particles of each mineral can be also calculated from the same measurements. Although this method was designed primarily for application to the coarse and medium granites, it can be extended also to the finer ones by drawing the lines upon camera-lucida drawings made from thin sections of such granites under polarized light. Certain microscope attachments have made this work less laborious. As the quartz is the source of the vitreousness of the rock the determination of its amount is important.

Polish.—Besides the manifest object of the test for polish it also facilitates exact descriptions of color and comparisons between different granites. The size of the mica plates determines the brilliancy and durability of the polish more than their number does—that is, a considerable number of very minute mica plates is not objectionable.

Hardness.—As pointed out by Hawes,[40] the hardness of certain granites is not due entirely to the quartz, which is always equally hard and brittle and which the tools do not cut but crush, but to the feldspar, which is of variable hardness and, it might be added, has different cleavages, and the proportion of which in relation to quartz also varies. Rosiwal,[41] adopting a principle established by Toula, takes a piece of smooth unpolished granite of about 2 grams weight and rubs it with emery (of 0.2 millimeter diameter of particle) upon a glass or metal plate for six or eight minutes until the emery loses its effectiveness. The granite is then weighed again and its loss of volume calculated. He found, assigning to emery an arbitrary value of 1,000 as representing its average hardness, that granite

[39] See Rosiwal, August, Ueber geometrische Gesteinsanalysen; ein einfacher Weg zur ziffermässigen Feststellung des Quantitätsverhältnisses der Mineralbestandtheile gemengter Gesteine: K.-k. geol. Reichsanstalt Verh., vol. 32, pp. 143–175, 1898.

[40] Hawes, G. W. (edited by Merrill), Granite; Building stones of the United States and statistics of the quarry industry: Tenth Census, vol. 10, pp. 16–18, 1888.

[41] Neue Untersuchungsergebnisse über die Härte von Mineralien und Gesteinen: K.-k geol. Reichsanstalt Verh., 1896, p. 488.

from nine localities showed the following degrees of hardness: 31.7, 38.1, 41.7, 44.8, 48.4, 50.7, 52.9, 56.6, and 67.1. The extremes of these figures show that some granites have a general hardness more than twice as great as others.

J. F. Williams[42] proposed to determine the relative hardness of granites by noting the rate of penetration of a drill of a given diameter, or by measuring the distance to which such a drill will penetrate without being sharpened, or the amount of surface of rough-pointed granite which can be reduced to a bush-hammered surface per hour. Since the introduction of pneumatic drills and surfaces these methods can be easily applied.

The United States Bureau of Standards expects to devise a machine for the satisfactory determination of the relative hardness of building stones.

Compressive strength.—The methods of testing the strength of building stones have grown in precision. The first requisite is that the cubes to be tested should be sawed by diamond saws and not hammered out. The next is that the direction of both rift and grain should be indicated thereon, and that three cubes should be tested, one with pressure applied parallel to the direction of the rift, one with pressure applied parallel to that of the grain, and the third with pressure applied at right angles to rift and grain. Where the rift and grain are pronounced the three results will differ. Compressive strength is now tested by the United States Bureau of Standards, both dry and wet, after two weeks' immersion in water, and also after 10 to 30 freezings and thawings.

Transverse strength.—The transverse strength should be tested both across the rift and with it, these directions being indicated on the block by the quarry foreman. The length of the span, the breadth and depth of the piece, and the weight of the load are taken into account in arriving at the modulus of rupture, given in pounds per square inch.

Tensile strength.—The test for tensile strength is useful in some building stones, particularly those designed for delicate carving. Small blocks are sawn out shaped somewhat like the figure 8 and pulled apart. The results are given in pounds per square inch. Of course, in a granite the results would differ if tension were applied with the rift or the grain or diagonal to both.

Porosity.—Buckley[43] points out that the danger from frost depends not upon the amount of absorption but upon the size of the pore space. Rocks with large pore spaces stand frost better than those

[42] Igneous rocks of Arkansas: Arkansas Geol. Survey Ann. Rept. for 1891, vol. 1, p. 41, 1891.

[43] See Buckley, E. R., Building and ornamental stones of Wisconsin, pp. 68, 69, 372–376, 400, 413, 1898.

with small ones, because they do not retain the water that they absorb. Tests of porosity are therefore important. Buckley used the dry and saturated weights obtained for the samples used in computing the specific gravity.

The difference in these weights was multiplied by the specific gravity of the rock. This amount was added to the dry weight, giving the sum. The difference of the dry and saturated weights multiplied by the specific gravity of the rock was then divided by the sum. This last result is the actual percentage of pore space compared with the volume of the sample tested.

Absorption.—The Bureau of Standards gives the results of tests of water absorption in percentage by weight. Buckley [44] describes a method of testing absorption.

Behavior under fire.—The test for behavior under fire is best applied to saturated specimens, which are then exposed in a laboratory furnace to a temperature up to 1,500° F. and the effect noted. Some of them can be allowed to cool gradually, but others should be immersed quickly in cold water; or they may be exposed to high temperature while under compression and then cooled slowly or quickly.[45]

Recent studies of the cause of the disintegration of granite under fire by Sosman [46] and Tarr [47] show this cause to be twofold—(1) the wedging and straining consequent on the different coefficients of thermal expansion of the constituent minerals; (2) a like effect due to the "rapid volume increase of quartz as its 575° inversion point is approached and by its final sudden increase in volume at 575°."

Specific gravity.—The specific gravity is the weight of the stone at 16° C. compared with that of the same volume of distilled water at 4° C. All air should first be removed from the piece to be tested by boiling in distilled water. The specific gravity is also required for the test of porosity.

Weight per cubic foot.—The weight of the dry stone per cubic foot is obtained by multiplying its specific gravity by the weight of a cubic foot of water, but from this there should be deducted "the weight of a quantity of stone of the same specific gravity equal in volume to the percentage of the pore space in the stone." [48] This gives the actual weight of the stone free from interstitial water.

Coefficient of expansion.—Finally, it may be desirable to obtain the coefficient of expansion of a granite intended for some particular construction. The expansion of certain granites was determined at

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[44] Idem, pp. 396–398.

[45] Idem, pp. 73, 411.

[46] Day, A. L., Sosman, R. B., and Hostetter, J. C., The determination of mineral and rock densities at high temperatures: Am. Jour. Sci., 4th ser., vol. 37, pp. 1–39, 1914. Sosman, R. B., A study of some heating tests: Econ. Geology, vol. 11, pp. 86, 87, 1916.

[47] Tarr, W. A., A study of some heating tests, and the light they throw on the cause of the disaggregation of granite: Econ. Geology, vol. 10, pp. 348–367, 1915; vol. 12, p. 280, 1917.

[48] Buckley, E. R., op. cit., p. 70.

the Watertown Arsenal by hot and cold water baths. The stones thus tested were afterward subjected to the test of transverse strength, when it was found that they had lost 16.93 per cent of their original strength.[49]

A list of the various tests applied to building stones by German testing institutions is given by Herrmann.[50]

GEOGRAPHIC DISTRIBUTION OF NEW ENGLAND GRANITE QUARRIES.

In Vermont the granite quarries lie all in the eastern half of the State and from the Canada line to Brattleboro. In New Hampshire they are on the northwest and southeast sides of the White Mountains, also about Concord and near the Vermont, Maine, and Massachusetts lines. In Maine the quarries are scattered along the coast and on its islands from the New Hampshire to the New Brunswick line; a very few are 40 to 55 miles inland. In Massachusetts, with unimportant exceptions, they all lie in the eastern half of the State, from New Bedford to Cape Ann. In Connecticut the quarries are mostly along the Sound, with a few in the western part of the State, along Connecticut River and the Rhode Island border. In Rhode Island they are almost entirely near Block Island Sound and the Connecticut line.

DESCRIPTIONS OF THE QUARRIES, GRANITES, AND PRODUCT.

METHOD OF TREATMENT.

The States will be taken up in the following geographic order: Vermont, New Hampshire, Maine, Massachusetts, Connecticut, and Rhode Island. The quarries will be taken up by counties in alphabetic order and by townships. The particulars of each quarry will be given in the following order:

1. Name and location of quarry; name and office address of operator.
2. The granite (specimen No.), its trade and technical names; its color, texture, minerals, estimated mineral percentages; its chemical composition and physical qualities, as shown by any available analyses or tests.
3. The quarry, date of opening, and approximate dimensions.
4. Rock structure, comprising sheets, joints, headings, their strike, dip, and spacings; courses of rift, grain, flow structure, dikes, and veins; dimensions of "knots," width of discoloration. Where the structure is complex, a diagram of the courses is given.
5. Transportation, method, and distance to dock or railroad.
6. The product, its uses, and the names and location of a few specimen buildings and monuments.

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[49] Report of the tests of metal, etc., made with the United States testing machine at Watertown Arsenal, Mass., p. 320, (1895)–1896.

[50] Herrmann, A., Steinbruchindustrie und Steinbruchgeologie, pp. 10 et seq., Berlin, 1899.

The quarry descriptions for each State are preceded by a section on the geographic distribution of its quarrying centers, accompanied for several of the States by a map and followed by a chapter on the geologic relations of the granites. In some cases, however, instead of a State map, a map showing the location of the quarries in each important quarrying center precedes the description of its quarries, and the geologic relations of the granite of that center are also considered separately.

An economic classification of all the granites of New England appears at the end of the descriptions in tabular form (pp. 419–435). In one table the trade name, general color and tint, shade, grade of texture, and scientific name of each granite are given in separate columns, and also page references to the detailed descriptions. In another table most of the granites are classified by color and shade.

VERMONT.

DISTRIBUTION OF THE GRANITES AND QUARRYING CENTERS.

Not until a contour map of the mountainous portions and of the eastern half of Vermont is completed and a careful geologic survey based upon such a map is made will the geographic distribution and extent of the granite areas of the State be accurately known. According to the geologic map of Vermont traced and compiled by the authors of the State report of 1861[51] and also according to the geologic map of Orange and parts of Washington and Windsor counties by C. H. Richardson,[52] a series of granite areas, varying greatly in size but mostly small, extend in a north-northeasterly direction between the central Green Mountain axis on the west and Connecticut River on the east for almost the entire length of the State.

The distribution by counties of all the granite-quarrying centers and prospects of Vermont described in this bulletin is shown in Plate I. At the extreme north end of the State, in Orleans County, granite is quarried in Derby, east of Lake Memphremagog. Near the northeast corner of Caledonia County, the next county south, there is a granite quarry in Newark; and there are several quarries in Kirby, about 14 miles south of Newark. There are also several quarries near the western corner of this county, 20 to 23 miles west of Kirby, in Hardwick; and the quarries of Ryegate and Groton lie near its southern edge. In Washington County, the southern half

[51] Hitchcock, C. H. and E., jr., and Hager, A. D., Report on the geology of Vermont, vol. 2, pl. 1, 1861. This map, valuable as it is, can to-day hardly be regarded as more than a reconnaissance map. Some of its granite areas are wrongly located, and granite has been found where the map does not show any.

[52] Richardson, C. H., The terranes of Orange County, Vt.: Vermont State Geologist Rept., 1902, pls. 9, 9a.

of which adjoins Caledonia on the west, there are three groups of quarries, the Woodbury quarries, at the north, and east of them a quarry in Cabot; south of Woodbury the quarries in Calais; and 20 miles southwest of Woodbury and 8 miles southeast of Montpelier, the quarries of Barre, which is the chief granite-producing center of the State. A few of the Barre district quarries lie south of the Orange County line. About 20 miles southwest of Barre is the granite prospect of Randolph, in Orange County. In the northern part of Windsor County is the small but important white granite area of Bethel; 10 miles southwest of it is a quarry in Rochester; 21½ miles nearly south-southwest of Bethel is another but very small white granite area in Plymouth, and 33 miles southeast of Bethel and near the Connecticut is the green syenite of Mount Ascutney, in Windsor and West Windsor. Finally, in Windham County, toward the southern border of the State, 37 miles south-southwest of Ascutney, near Brattleboro and the Connecticut, are the light-granite quarries of Dummerston.

GEOLOGIC RELATIONS OF VERMONT GRANITES.

The contact of the granites of Bethel, Barre, and Woodbury with schist or slate and the inclusions of these rocks in the granites of Barre and Ryegate have already been described (pp. 84, 88, 64). The granite of Bethel contains inclusions of very fine black biotite-orthoclase-oligoclase schist quite unrelated to the schist and slate surrounding that granite (pp. 155, 158). As is shown on page 160, the granite of Plymouth is surrounded by and in contact with schist. On Buffalo Hill, in Hardwick, the granite is in contact with a biotite-quartz schist.

The general inference from these contacts and inclusions is that the gray biotite granite of Barre, Calais, and Woodbury, the white quartz monzonite of Bethel and Plymouth, the gray biotite granite of Ryegate, and the light and dark gray quartz monzonites of Derby and Hardwick were intruded into certain mica schists and mica slates which are metamorphosed clayey and sandy sediments. Whether the intrusion of granites as diverse in character as those of Barre, Bethel, and Hardwick took place at the same time can not yet be determined. The green syenite (hornblende-augite granite) of Mount Ascutney, in Windsor, is in contact with a mass of schist which crops out along the base of the mountain a little below the Norcross quarry and has been carefully traced by Daly[53] on three sides of the syenite mass and mountain. He has also described the changes brought about in the schist by the intrusion of the syenite[54]

[53] Daly, R. A., The geology of Ascutney Mountain, Vt.: U. S. Geol. Survey Bull. 209, pl. 7, 1903.

[54] Idem, pp. 33, 34.

and shows a biotite granite intrusive in the syenite on the eastern flank of the mountain.

In view of the certain amount of pressure needful for the slow cooling and crystallization of granite the schist masses intruded by these various granites must have been thicker than they now are. The exposure of the present granite surfaces has been brought about by the erosion of the schist masses.

Views have changed as to the age of these schists. On Hitchcock and Hager's map the granite areas are represented as surrounded by "calciferous mica schist" which was regarded as not later than Devonian.[55] Richardson[56] in his papers and map subdivided the "calciferous mica schist" belt of Hitchcock and Hager into a calcareous formation (in places a marble but containing schist phases) which he finally designated Waits River limestone, and an overlying noncalcareous schist, the Vershire schist. He associates the latter formation with a certain belt of slate that flanks the central Green Mountain axis on the east, extends from Lake Memphremagog south to Barnard, and includes the roofing slate of Northfield and Montpelier. This slate he finally designated the Memphremagog slate. About 3 miles west of the head of Lake Memphremagog, at Willards Mill, Castlebrook, Magog, Province of Quebec, this slate bears abundant graptolites of lower Trenton age.

In 1912 Richardson[57] announced the discovery in Irasburg of a basal Ordovician conglomerate, and in a more recent paper,[58] in referring to the same locality, he reports pre-Ordovician granites intruding Cambrian sedimentary rocks, and also announces the discovery of Ordovician graptolites, with determinations by R. Ruedemann, in the calcareous or noncalcareous sedimentary rocks of Newport, Irasburg, Craftsbury, Hardwick, Woodbury, Calais, Montpelier, and Northfield, establishing the Ordovician age of the slate belt from Lake Memphremagog to Northfield and Barnard. He also found Ordovician graptolites in the slates of Barre. The conclusion is thus reached that the mica schists and mica slates intruded by the granites of Newport, Hardwick, Woodbury, Calais, Barre, and Bethel are very probably all of Ordovician age. Richardson is careful to state, however, that although the intruded rocks are Ordovician the intrusion may not have taken place until

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[55] Op. cit., vol. 1, p. 470.

[56] Richardson, C. H., The Washington limestone in Vermont: Am. Assoc. Adv. Sci. Proc., vol. 47, pp. 295–296, 1898; The terranes of Orange County, Vt.: Vermont State Geologist Third Rept., pp. 84, 97, 98, pl. 9, 1902; The areal and economic geology of northeastern Vermont: Vermont State Geologist Fifth Rept., pp. 86, 90, 1906; The geology of Newport, Troy, and Coventry: Vermont State Geologist Sixth Rept., pp. 274–279, 1908.

[57] Richardson, C. H., The terranes of Irasburg, Vt.: Vermont State Geologist Eighth Rept., p. 151, 1912.

[58] Richardson, C. H., The geology of Calais, East Montpelier, and Berlin, Vt.: Vermont State Geologist Tenth Rept., pp. 112–145, 1916.

post-Devonian time—that is, during the second crustal movement and metamorphism after the deposition of the Ordovician sediments.

Daly,[59] basing his opinions on Richardson's results and inferences, regards the schist of Mount Ascutney as of Trenton or pre-Trenton age and the intrusion of the syenite as "of later date than the last great period of rock folding which has affected the Ascutney region," and says that "the balan e of probability makes it of post-Carboniferous and pre-Cretaceous age."

Evidences are not wanting in the composition and microscopic structure of the granites and in their larger structures as exposed at the quarries that since their intrusion they have been subjected to one and possibly several crustal movements. (See pp. 127, 128, 153.)

The basic dikes that traverse the granite or their inclosing schists at Barre, Groton, and Mount Ascutney are of later, possibly Triassic, date.

OUTLINE OF EARLIER HISTORY OF VERMONT GRANITES.

The general earlier history of the granites and associated rocks of eastern Vermont may be tentatively put in the following simple form:

1. In Algonkian time there was a period of sedimentation followed by the intrusion of granitic rocks into the sedimentary beds. These granities are the present gneisses of the Green Mountain range.

2. At the end of Algonkian time a crustal movement metamorphosed the Algonkian sediments into schists and quartzite and the granites into gneisses. This movement was accompanied by folding and elevation. The earlier mountain system of the State was thus formed.

3. In early Paleozoic time a large area of Algonkian rocks was submerged and received sediments resulting from the erosion of Algonkian land masses, together with calcareous sediments largely of organic origin.

4. At the end of Lower Cambrian time a minor crustal movement took place, subjecting the Lower Cambrian beds to erosion, followed by a resubmergence at the beginning of Ordovician time. Evidence of this movement is obscured in many places by the effect of the crustal movement noted below (5).

5. At the end of Ordovician time a crustal movement took place, metamorphosing the Cambrian and Ordovician sediments into schist, quartzite, slate, and marble, and powerfully folding and also elevating them. The later mountain system of the State was then formed. Some of these schists and slates are those which now surround the granite areas.

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[59] Op. cit., pp. 20, 21.

6. After a long interval, probably at the end of Devonian or Carboniferous time, another crustal movement occurred, accompanied by the intrusion of the Ordovician schist mass by granitic material in a state of fusion with superheated water. The intrusion produced in places further changes in the schist and also injected it with dikes of pegmatite. Fragments of the schist became included in the granite.

7. Not long after the crystallization of the granite it was traversed by granite dikes (pegmanite and aplite).

8. Mount Ascutney shows two intrusions, one of the Ordovician schist by the syenite, and a later one of the syenite by a biotite granite. The age of the last is quite uncertain.

9. The schist and granite masses were traversed, possibly in Triassic time, by basic dikes (diabase, etc.).

10. Atmospheric erosion of the Paleozoic schists and slates, begun at the close of Ordovician time, has finally removed those parts of the schist mass which covered the granite domes. This process of erosion has been accelerated by successive uplifts.

THE GRANITE RAILROADS.

The granite industry of Vermont owes no small part of its present prosperity to "granite railroads," which connect not only groups of quarries but every quarry in each group with the main line, although these quarries are situated at considerable elevations and are inconveniently related to one another. Plate II shows the intricate character of the granite railroad about Millstone Hill near Barre; figure 20 gives a general idea of that connecting Robeson Mountain in Woodbury with Hardwick, and figure 35 that leading from Christian Hill to Bethel.

THE QUARRIES, THEIR GRANITE AND FINISHED PRODUCT.

CALEDONIA COUNTY.

HARDWICK.

Perkins, in 1906, called attention to a fine light granite quarried in Hardwick by the Northern Granite Co., from which more than 50 statuettes had been cut. He also mentioned granite quarries at Mackville, a mile south of Hardwick village, as then operated by the same company.[60] As these quarries were not in operation in 1907 they were not visited by the writer.

C. H. Richardson,[61] in a paper on the geology and mineralogy of Hardwick and Woodbury, gives a geologic map of Hardwick showing three granite areas, one north of the village (West Hill and Tuckerville area), one south of it (Mackville area) and one west-southwest of it which includes Buffalo Hill and the Mack quarries.

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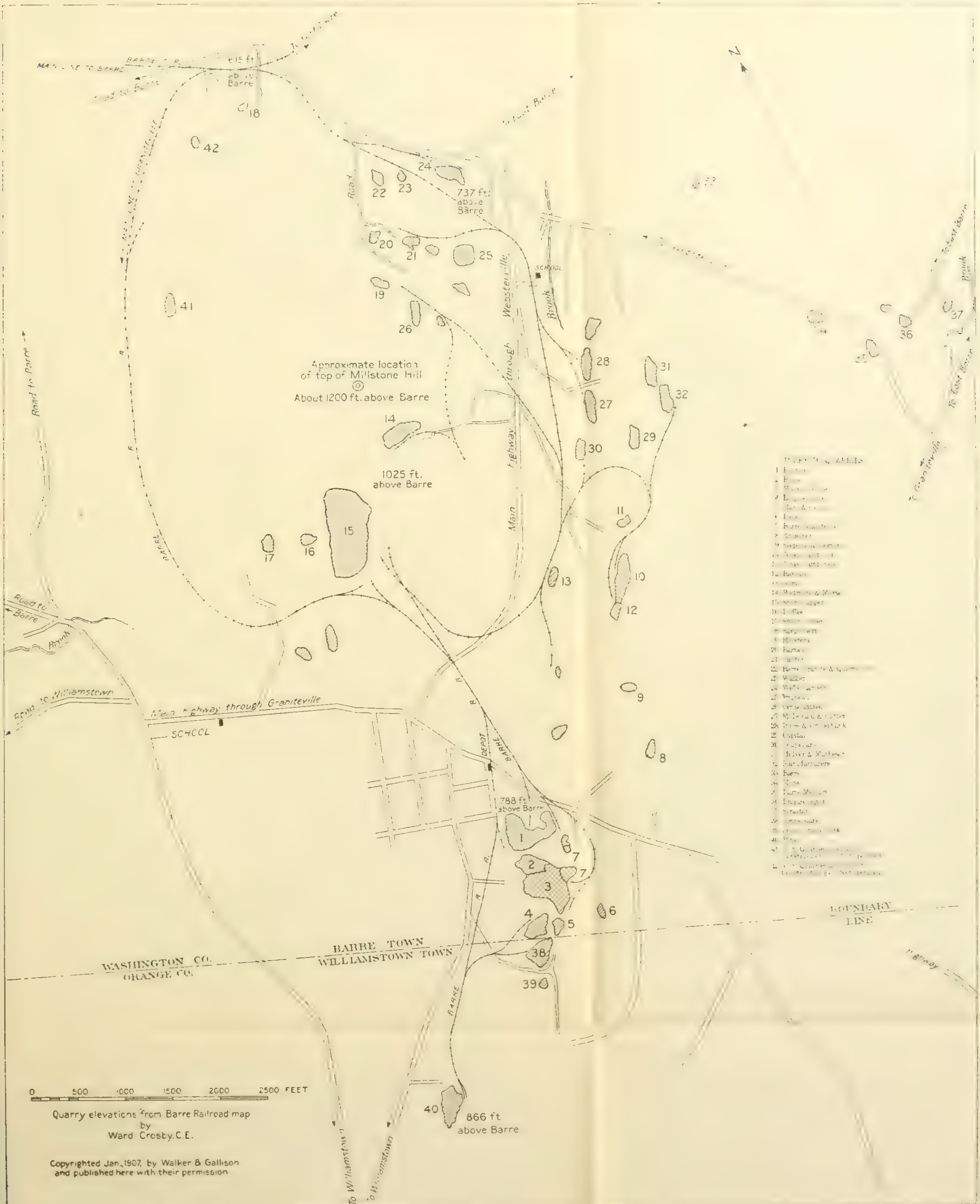
[60] See Perkins, G. H., Vermont State Geologist Fifth Rept., p. 105, 1906.

[61] Vermont State Geologist Ninth Rept., pp. 294–336, pl. 64, 1914.

MAP OF VERMONT AND NEW HAMPSHIRE SHOWING LOCATION OF GRANITE QUARRIES.



MAP OF BARRE, VT., SHOWING LOCATION OF GRANITE QUARRIES.

In 1915 the **Northern Granite Co.,** 168 College Street, Burlington, operated a small quarry south-southeast of Hardwick village, producing fine dark granite on its south side and fine light granite on its north side. The stone is used for monuments. The quarry has been idle since 1915.

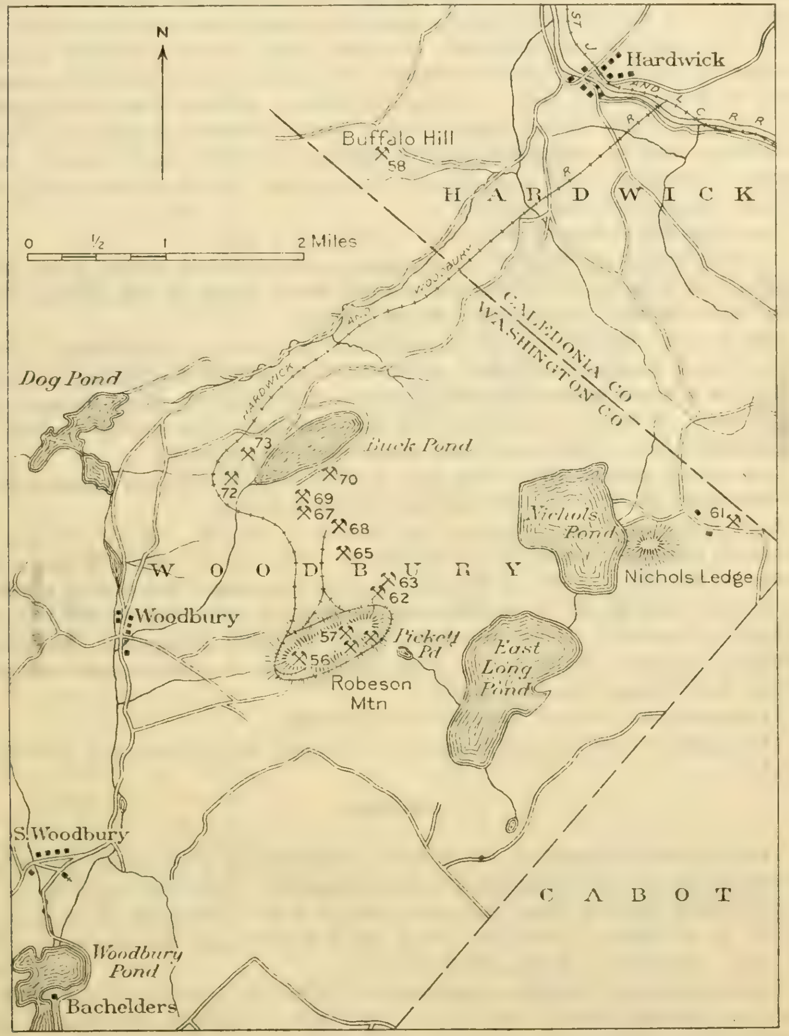


FIGURE 20.—Map compiled from various sources showing approximate locations of granite quarries in Woodbury, Washington County, Vt. Quarries: 56, Fletcher; 57, Woodbury Granite Co.; 61, Carter; 62, Carson; 63, Ainsworth; 65, Vermont White; 67, Webber, new; 68, Webber, main; 69, Imperial Blue; 70, Old Quarry; 72, Leach; 73, Chase.

The **Buffalo Hill quarry** is on Buffalo Hill, about 2½ miles S. 60° W. from Hardwick village and about 500 feet above it. (See map, fig. 20.) Operator, Hardwick Granite Co., Hardwick. Idle since 1917.

The granite (specimen D, XXIX, 58, a and d), "dark-blue Hardwick," is a quartz monzonite of dark-gray shade, a little darker than "dark Barre" and a trifle lighter than "dark Quincy." Its texture is medium, with feldspars up to

0.3 inch and mica to 0.2 inch, generally even grained but with sparse clear porphyritic feldspars up to 0.4 inch, inclosing the feldspars, quartz, and mica. Its constituents, in descending order of abundance, are smoky quartz with hairlike crystals of rutile, with cavities in sheets parallel to rift cracks and with another shorter and rarer set at right angles to the first; milk-white soda-lime feldspar (oligoclase to oligoclase-andesine), much kaolinized, somewhat micacized and epidotized, and containing calcite; in about equal amount with this feldspar a clear to bluish-white potash feldspar (microcline with a little orthoclase), some of it kaolinized, some inclosing particles of all the other constituents; olive-colored biotite (black mica), with a little muscovite or bleached biotite. Accessory: Pyrite, magnetite, apatite, zircon (crystals), and allanite. Secondary: Kaolin, a white mica, epidote, and calcite. The soda-lime feldspar is radially intergrown with quartz.

The stone effervesces slightly with muriatic-acid test.

An estimate of the mineral percentages by the Rosiwal method gives these results with a mesh of 0.4 inch and a total linear length of 38.8 inches: Feldspar, 62.05; quartz, 21.75; mica (biotite), 16.20.

The average diameter of all the particles by the same calculation is 0.093 inch; that of feldspar, 0.106 inch; of quartz, 0.122 inch; and of mica, 0.052 inch.

This is a bright stone with strong contrast between the white feldspar and black mica. It takes a fair polish and hammers light with marked contrast to the polished face, which shows some pyrite and less magnetite.

The quarry, opened about 1887, was in 1907 a small irregular opening 20 to 30 feet deep. It is a "boulder quarry" without sheets.

Rock structure: Joint systems—(a), strike N. 30° W., dip 35° W., spaced about 10 feet; (b), strike N. 45° E., dip 40° NW., spaced about 10 feet; (c), strike N. 25° W., dip 50° to 75° NE., spacing irregular. The rift is reported as vertical with N. 50° E. course, and the grain as about like joints (a), but neither is marked. There are some white, probably feldspathic, and black biotitic "streaks," really veins, with curving course. Rusty stain up to 6 inches thick appears on joint faces.

Transportation, by cart, 2½ miles, to Hardwick.

The product is used for monuments, particularly for polished and rock-faced work.

KIRBY.

The quarries in Kirby are all on Kirby Mountain, in the eastern part of the township, about 9 miles northeast of St. Johnsbury. (See map, fig. 21.)

The **Grout quarry** is on the south side of Kirby Mountain, 2½ to 3 miles N. 20° W. of North Concord and about 450 feet above the station there. (See fig. 21.) Operator, A. Rossi, North Concord.

Grout quarry gray granite (specimen D, XXIX, 76, a) is a biotite granite of light to medium, slightly bluish-gray color and of medium inclining to fine, even-grained texture with feldspars up to 0.25 inch and mica to 0.1 inch. Its constituents, in descending order of abundance, are clear to translucent potash feldspar (microcline, with inclusions of the other constituents, and also orthoclase), light smoky quartz with cavities in sheets with a set of cracks parallel to them, milk-white soda-lime feldspar (albite to oligoclase-albite) much kaolinized and with some white mica, biotite (black mica), and a little muscovite or bleached biotite. Zircon is an accessory mineral. Neither magnetite nor pyrite was detected. Secondary minerals, kaolin and a white mica. No effervescence with muriatic-acid test.

This is a bright stone, but the fineness of its mica and the light shade of its quartz preclude strong contrasts.

The quarry, opened about 1899, consisted in 1907 of two openings, the northern and upper one 40 by 25 feet and 10 feet deep; the lower one 70 feet square and 3 to 5 feet deep.

Rock structure: The sheets, 6 inches to 4 feet thick, but obscure in the upper opening, strike N. 55° E. and dip 25° SE. Joints (a), vertical, strike N. 25° W., spaced 1 foot to 2 feet 6 inches to 50 feet; (b) strike N. 85° E., dip 55° N., forming the south wall, spaced 6 to 8 feet; (c) strike N. 80° W., dip 40° N. 20° E., spaced 9 feet. The rift is reported as vertical, with N. 70° E. course, and grain as horizontal. The flow structure, consisting of streaks of biotite, is parallel to the rift. There are some biotitic knots. Rusty stain is confined to the surface and the thinnest sheets next to it.

Three aplite dikes, 1 foot to 6 feet 6 inches thick, strike N. 80° E. This aplite is described on page 45.

Transportation, by cart, 5 to 6 miles, to rail at Concord.

The product was used for monuments. Quarry operated in 1915 but reported abandoned in 1916.

The **Burke quarry** is on the west foot of Kirby Mountain, about 1,000 feet N. 60° E. from the Kearney Hill quarry and 2⅛ miles roughly N. 50° W. from North Concord. (See fig. 21.) Operator, Kirby Granite Co. (W. J. Chapman), East Burke. Idle since 1916.

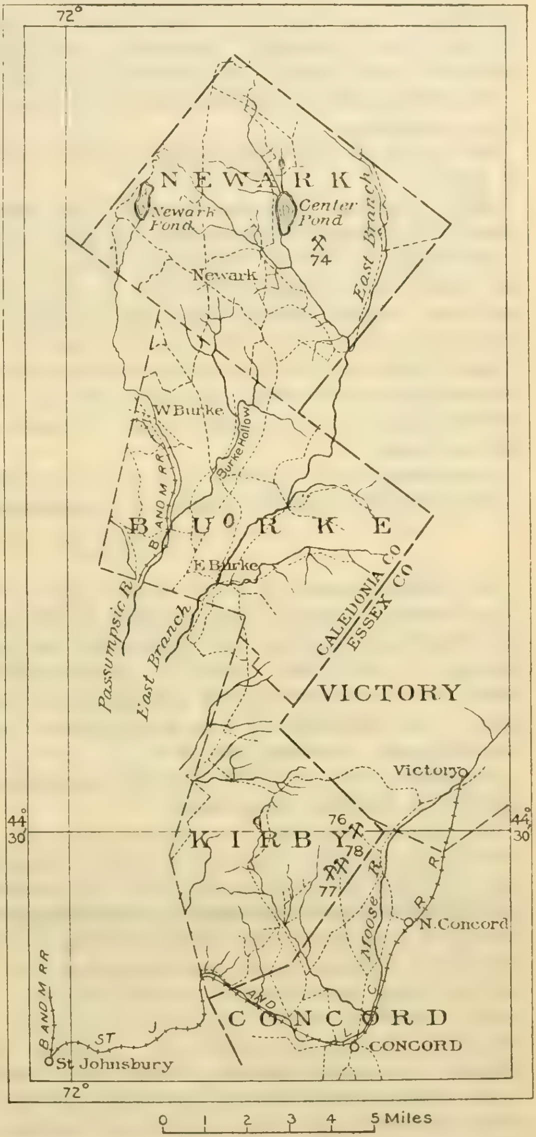


FIGURE 21.—Map of Kirby, Burke, and Newark, Vt. From Beers's Atlas. Quarries: 74, Packer; 76, Grout; 77, Kearney Hill; 78, Kirby Granite Co.

The granite (specimen D, XXIX, 78, a) is a quartz monzonite of light to medium gray color, and of medium inclining to fine, even-grained texture, with feldspars up to 0.25 inch and mica to 0.1 inch. Its constituents, in descending order of abundance, are light smoky quartz with hairlike crystals of rutile, and sheets of cavities with cracks parallel to them; milk-white soda-lime feld-

spar (oligoclase) much kaolinized and micacized, with some carbonate and epidote, and in places intergrown with quartz in vermicular structure; clear to scarcely bluish potash feldspar (microcline with inclusions of oligoclase, quartz and mica, also orthoclase micacized); biotite (black mica) some of it chloritized; and muscovite (white mica). Accessory: Very little magnetite, apatite, zircon, and rutile. Secondary: Kaolin, a white mica, epidote, zoisite, carbonate, and chlorite. No effervescence with muriatic-acid test.

This stone closely resembles that of the Grout quarry in its color and weakness of contrasts.

The quarry in 1907 measured about 175 by 100 feet and from 10 to 20 feet in depth.

Rock structure: Between this and the abandoned Kearney Hill quarry there is an outcrop of schist, either an inclusion or the original schist capping, which strikes N. 15° E. The sheets, from 1 to 5 feet thick, dip 10° S. There are three sets of joints—(a), strike N. 25° to 30° W., dip 30° W., forms the east wall, recurs 100 feet west, and has some parallel subjoints; (b), discontinuous, strike N. 5° W., dip 65° E. to 90°, spaced 100 feet; (c), discontinuous, strike N. 75° E., vertical, spaced 2 to 50 feet. The rift is reported as horizontal and marked, and the grain as vertical with N. 70° E. course Biotitic knots up to 2 inches across. There is little or no rusty stain below the top sheet.

Transportation, by cart 5½ miles to rail at Concord.

The product is used for rough and cut monuments.

NEWARK.

The **Packer quarry** is in the eastern part of Newark, on the west side of a ridge between Center or Island Pond on the west and the East Branch of the Passumpsic on the east. This ridge lies north of Burke Mountain and southeast of Ball Hill. There is a marked east-west sag in the ridge. The opening is a little north of the sag on a gently sloping bench below the steeper part of the ridge and 363 feet above Center Pond, about east-southeast from its south end. (See map, fig. 21.)

The quarry, idle since 1915, has been operated by the Newark Granite Co. (address H. D. Packer), West Burke.

The granite (specimen D, XXIX, 74, b), "Newark pink," is a biotite granite of light pinkish-gray color and of coarse, even-grained texture, with feldspars up to 0.8 inch and mica to 0.15 inch. Its constituents, in descending order of abundance, are light pinkish-gray potash feldspar (orthoclase and microcline), some of it intergrown with soda-lime feldspar or with inclusions of it, slightly kaolinized; medium smoky quartz with cavities in sheets; cream-colored, in places slightly greenish-gray striated soda-lime feldspar (albite to oligoclase, albite), much kaolinized, and with some white mica and carbonate; biotite (black mica), some of it chloritized. Accessory: Magnetite, pyrite, titanite, and allanite. Secondary: Kaolin, a white mica, epidote, and calcite.

An estimate of the mineral percentages by the Rosiwal method, with a mesh of 0.6 inch and total linear length of 46 inches, yields these results: Feldspar, 64.80; quartz, 30.30; mica, 4.64; magnetite, 0.26. The average diameters of the particles obtained from the same calculation are: Feldspars (adding 20 per cent to the number as an estimate of the uncounted soda-lime particles), 0.162 inch; quartz, 0.106 inch; mica, 0.0406 inch. Average diameter of all particles, 0.123 inch.

The rock effervesces slightly with muriatic-acid test. W. T. Schaller, chemist of this Survey, finds that it contains 0.23 per cent of CaO (lime) soluble in

warm dilute acetic acid (10 per cent), which indicates a content of 0.4 per cent of $CaCO_3$ (calcium carbonate, calcite), the presence of which is also shown by the microscope.

The contrasts in this granite are chiefly between the smoky quartz and the combined feldspars. It has very sparse porphyritic feldspars up to 1.5 by 0.5 inch, but these are hardly numerous enough to impart to it a technically porphyritic texture. The polished face shows magnetite in minute particles and very few of pyrite. The polish is fairly good, the mica particles, although somewhat large, not being very abundant.

Rock structure: The sheets on the steeper, higher part of the ridge, 110 feet above the bench carrying the outcrop sampled, are from 3 to 6 feet thick and not far from horizontal. Joints (a) strike N. 30° E., dip 70° W.; (b) strike N. 5°.W., vertical. The rift is possibly east-west and vertical. The granite for a thickness of 110 feet and presumably to the top of the ridge is the same as that described, but recent prospecting, it is claimed, indicates the presence of finer-grained granite between the opening sampled and the pond.

The nearest railroad is 8 miles away.

FIGURE 22.—Map of Ryegate, Groton, and part of Topsham, Vt. From Beers's Atlas. Quarries: 80, Benzie; 87, Ricker.

RYEGATE.

TOPOGRAPHY.

The **Ryegate quarries** are on the southwest and northeast sides of Blue Mountain, a northwest-southeast ridge about 5 miles west of Connecticut River, in the east-central part of the town. (See maps. Pl. I and fig. 22.)

GENERAL GEOLOGY.

A mica schist crops out in the village of South Ryegate with a very steep dip and appears to continue 3 miles north onto a bench on the southwest side of Blue Mountain and 770 to 800 feet above the village. The granite extends

from the back or northeastern part of the bench to the top of the ridge. At a point about 770 feet above the village the foliation and bedding of the schist strike N. 50° W. and dip 55° NE. In places the schist is coarse and speckled, but with it is interbedded a very quartzoze mica slate (quartz-biotite-muscovite-epidote).

"RYEGATE GRANITE."

The granites of Blue Mountain are quartz monzonites and biotite granites of light and medium, more or less bluish gray color and of medium, very rarely fine to medium, even-grained texture, and are used chiefly for rough or hammered monuments. All the quartz monzonites of Ryegate ought to cut light.

GEOLOGY OF RYEGATE QUARRIES.

The inclusions of schist in "Ryegate granite" have already been described on page 65 and shown in Plate III, *B*, at the right. The sheets, from 6 inches to 12 feet thick, are in some places horizontal and in others dip from 5° to 25° S. 25°, 45°, 60° W., also gently south and S. 45° E., on the southwest side of the mountain. Their relation to that slope of the mountain is apparent at the Frazer quarry and on the ridge northeast of the Italian quarry for some 300 feet above it; but at the Rosa quarry, on the other side of the axis of the ridge, the sheets range from horizontal to 10° E., thus indicating a broad anticlinal sheet structure. There are four sets of joints, or two sets each with its complementary one. The strikes are N. 70°–90° W., N. 5° E., N. 50° W., and N. 30° E. The flow structure, shown by biotitic streaks, strikes N. 70° W. and dips 20°–25° N. 20° E. The rift is reported as vertical with north-south or N. 55° E. course, and the grain as horizontal. A 22-inch basic dike crosses the granite on the northeast side with a N. 65° W. course. The granite for a foot on either side of it has subjoints 0.5 to 3 inches apart parallel to the dike. Small pegmatite dikes have N. 50° W. and N. 15° E. courses.

QUARRIES.

The **Gibson quarry** is on the southwest side of Blue Mountain, 940 feet above the village of South Ryegate. Operator, Ryegate Granite Works Co., South Ryegate.

The granite (specimen D, XXIX, $\overline{81}$, a, from upper sheets), "Ryegate," is a quartz monzonite of light to medium gray shade and medium, even-grained texture with feldspars up to 0.4 inch and mica to 0.1 inch. Its constituents, in descending order of abundance, are very light smoky quartz with fluidal and other cavities in sheets and a set of cracks parallel thereto, also with traces of another set of sheets at right angles to these; milk-white soda-lime feldspar (oligoclase) slightly kaolinized with a little white mica and epidote, some of it intergrown with quartz in vermicular structure; bluish potash feldspar (microcline, also orthoclase) similarly intergrown; biotite (black mica) and a little muscovite or bleached biotite. Accessory: Titanite, zircon crystals, apatite, and pyrite. Secondary: Epidote, kaolin, and white mica.

The rock does not effervesce with cold dilute muriatic acid. Its contrasts are weak.

The quarry, opened in 1906, was about 200 feet square and from 2 to 4 feet deep in 1907.

Rock structure: The sheets, 6 inches to 4 feet thick, dip 15° S. 25° W. and are normal. There is but one set of joints, strike east, vertical, at irregular

intervals, and discontinuous. The rift is reported as vertical north-south and the grain as horizontal. Flow structure (biotitic streaks) strikes N. 70° W. and dips 20° N. 20° E. A schist inclusion measures 12 by 8 inches. Small vertical pegmatite dikes strike N. 15° E.

Transportation, by cart, 3 miles, to cutting sheds at South Ryegate, 940 feet lower. The product is used for monuments and bases, and to some extent for building.

The **Morrison quarry** is on the southwest side of Blue Mountain, in Ryegate, about 940 feet above the village of South Ryegate and about 700 feet southeast of the Gibson quarry. Last operator, D. A. Morrison. Quarry abandoned in 1915.

The granite (specimen D, XXIX, $\overline{82}$, b) is a quartz monzonite of medium gray color and medium, even-grained texture, with feldspars up to 0.4 inch and mica to 0.2 inch.

This stone is identical with that of the Gibson quarry, but its contrasts are a little sharper.

The quarry, opened in 1900, measured about 400 by 200 feet, with an average depth of 20 feet in 1907.

Rock structure: The sheets, 1 to 5 feet thick, dip very gently south and southeast. There are two sets of joints—(a), strike N. 85° E., dip 70° S., forms a heading on the north side; (b), strike N. 30° E., dip 75° N. 30° W., is discontinuous and spaced very irregularly. The rift is reported as vertical north-south, and the grain as horizontal. Schist inclusions, 3 feet by 1 foot and 8 by 4 feet, are described on pages 21 and 65. (See also Pl. III, *B*, at the right.) Small pegmatite veins, "tight sets," are bordered with large biotitic spots and muscovite flakes.

Transportation, by cart 3 miles to South Ryegate, 940 feet lower.

The product was used for bases and hammered monuments.

The **Italian quarry** is on the southwest side of Blue Mountain, 940 feet above the village of South Ryegate and about 400 feet N. 60° W. from the Gibson quarry. Operator, Rinaldo Tonelli, South Ryegate.

The granite is a quartz monzonite of light to medium gray shade and medium, even-grained texture, identical with that of the Morrison and Gibson quarries.

The quarry opened in May, 1907, measured in August about 250 by 100 feet and about 5 feet in depth.

Rock structure: The sheets, 10 inches to 5 feet thick, dip 20° W. Only one set of joints, strike N. 50° W., dip 30° E., spacing 50 feet. The rift is reported as vertical with N. 55° E. course and the grain as horizontal, and both as equal.

The product is carted 3 miles to South Ryegate and used for bases and hammered monuments.

The **Frazer quarry** (formerly known as Hall's) is on the southwest side of the southeast spur of Blue Mountain, about 950 feet above South Ryegate. It is no longer operated.

The granite (specimen D, XXIX, $\overline{85}$, b) is a quartz monzonite of light to medium gray shade and of medium inclining to coarse, even-grained texture, with feldspars up to 0.4 inch and mica to 0.2 inch.

While the general shade of this stone differs but little from that of the Morrison and Gibson quarries, the contrasts between its minerals are much more marked.

The quarry measures about 300 feet square and from 5 to 20 feet in depth.

Rock structure: The sheets are normal, 1 to 12 feet thick, dipping 25° SW. There is but one joint, strike N. 70° W., dip 35° N. 20° E. A flow structure of biotitic streaks and sheets strikes N. 70° W. and dips 45° N. 20° E. In the west

half of the quarry this is so prominent as probably to detract from the value of the stone. Rusty stain along the sheet surfaces is up to 3 inches thick. (See on the natural removal of this stain by organic and carbonic acids, p. 69.)

The product had to be carted 3½ miles to South Ryegate.

The **Rosa quarry** is on the northeast side of a southeast spur of Blue Mountain, about 300 feet below its top and in line with its main axis. This quarry is about one-third of a mile by road from the Frazer quarry and about 1,100 feet above South Ryegate. Operator, Rosa Bros., South Ryegate.

The granite is of two kinds. The first, "fine gray" (specimen D. XXIX, $\overline{79}$, a), is a biotite granite of medium-gray shade and of fine, inclining to medium, even-grained texture, with feldspars up to 0.2 inch and mica to 0.1 inch. Its general shade is a trifle darker than that of the quartz monzonite of the Gibson quarry. Its constituents, in descending order of abundance, are translucent to very light bluish-gray potash feldspar (orthoclase and microcline); light smoky quartz with hairlike crystals of rutile, and fluidal and other cavities in sheets with cracks parallel thereto; whitish soda-lime feldspar (oligoclase), slightly kaolinized, micacized, and epidotized, in places intergrown with quartz in vermicular structure; biotite (black mica); and a little muscovite or bleached biotite. Accessory: Apatite, zircon crystals, titanite. Secondary: Kaolin, a white mica, epidote, limonite.

W. T. Schaller, a chemist of this Survey, finds that this stone contains 0.03 per cent of CaO (lime) soluble in warm dilute (10 per cent) acetic acid, which indicates the presence of 0.05 per cent of $CaCO_3$ (calcium carbonate). No carbonate was detected in thin section, nor any effervescence with muriatic-acid test.

The fineness of the texture of this stone precludes mineral contrasts.

The other granite (specimen D, XXIX, $\overline{79}$, b), "coarse gray," is a biotite granite of medium bluish gray color, and medium, even-grained texture, with feldspars up to 0.3 inch and mica to 0.15 inch. This is also a trifle darker than that of the Gibson quarry. Its constituents are like those of the fine gray, with the addition of calcite and more biotite. The stone effervesces with muriatic-acid test.

Its contrasts are stronger than those of the quartz monzonites of the Morrison and Gibson quarries.

The quarry, opened in 1906, measured in 1907 about 150 by 75 feet and from 10 to 25 feet in depth.

Rock structure: The sheets, 1 to 10 feet thick, are horizontal or dip to 10° E. There are three sets of joints—(a), strike east, dip 65° S., forms a 3-foot-wide heading on the north; (b), strike N. 70°–80° W., dip 40° N. 10°–20° E., spaced 1 to 25 feet, coated with epidote and slickensided; (c), strike N. 5° E., vertical, one only. The rift is reported as vertical with N. 60° E. course, and the grain as horizontal. The fine granite (specimen $\overline{79}$, a) occurs only north of heading (a). On the south edge of the quarry a vertical basic dike, 22 inches thick, strikes N. 65° E. (See p. 114.) Rusty stain measures 1 to 2 inches.

The product is carted nearly 4 miles to the cutting shed at South Ryegate and is used for hammered and rock-faced monuments and bases.

GROTON.

The **Benzie quarry** is in Groton about a mile S. 25° W. from the Wells River Bridge at Groton and 300 feet above it, and about 4½ miles S. 85° W. from Blue Mountain, is Ryegate. (See fig. 22.) Operator, Bonazzi Quarry Co. (Inc.), Montpelier.

The granite (specimen D. XXIX, 80, a), "Vermont blue," is a quartz monzonite of medium, very bluish gray color and even-grained medium inclining to fine texture. Its constituents, in descending order of abundance, are clear colorless to very light smoky or very light bluish quartz, with few cavities and brightly polarizing rift and grain cracks; translucent light-bluish soda-lime feldspar (oligoclase), somewhat kaolinized and with white fibrous mica, also a white mica in small scales, and some calcite; a little clear potash feldspar (microcline, also orthoclase), with inclusions of oligoclase, quartz, and biotite; biotite (black mica); and a little muscovite or bleached biotite. Some of the feldspars are minutely intergrown with quartz in vermicular structure. Accessory: Titanite, pyrite, zircon crystals, apatite, allanite. Secondary: Kaolin, a white mica, calcite, leucoxene. Effervesces with muriatic-acid test.

This stone is brilliant and markedly bluish, but its mineral contrasts are feeble.

The quarry, opened in 1896, measured in 1907 about 200 by 175 feet and from 40 to 60 feet in depth.

Rock structure: The sheets are normal, 1 to 10 feet thick, and range from the horizontal to a very low dip north and also east. The structure is shown in figure 23.

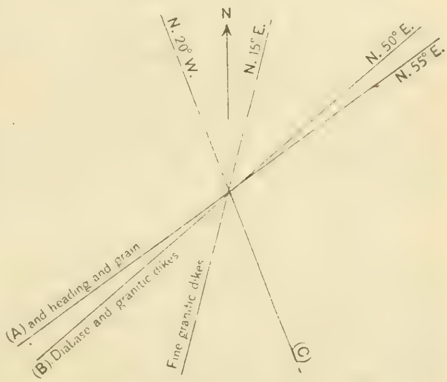


FIGURE 23.—Structure at Benzie quarry, Groton, Vt.

There are three sets of joints—(A), strike N. 55° E., vertical, spaced 15 to 50 feet, forms a rusty heading on the west wall, with short vertical subjoints at right angles to it; (B), strike N. 50° E. (diagonal to quarry), dip 60° S. 50° E., discontinuous and at irregular intervals: (C), strike N. 20° W. and vertical, discontinuous and rare. The rift is reported as horizontal, and the grain as vertical, with N. 55° E. course. There is a coarse "shake" structure in bands up to a foot thick parallel to the sheets, at points 25, 40, and 60 feet below the surface. (See p. 39.) There are biotitic masses on the west side parallel to joints (A), the course of which is also that of the grain, and thus also that of the flow. On the west wall is a dike of quartz monzonite (specimen D. XXIX, 80, b) 5 feet thick, of medium bluish-gray color and very fine, even-grained texture, with feldspars up to 0.1 and mica mostly under 0.5, exceptionally 0.1 inch. Its constituents are the same as those of the main granite. There are two dikes of similar quartz monzonite, but of dark, slightly bluish-gray color and extremely fine texture, with feldspars up to 0.06 (exceptionally 0.1) and mica to 0.04 inch. These dikes are 6 and 2 inches thick, strike N. 5° and 20° E., and dip 70° E. and 90°. Several pegmatite dikes, 1 to 6 inches thick, cross the entire quarry, cutting the first granite dike, some striking N. 17° W., others in various directions. There is also a 3-inch diabase dike on the west wall. It contains porphyritic augite crystals, some of which have been replaced by quartz or calcite or chlorite. A compressive strain is reported here as from all directions. Rusty stain is only an inch thick on sheets 10 feet below the surface.

The product was carted 1½ miles to the cutting shed at Groton. It was used for monuments and buildings. The fine stone of the granite dike was used

for special orders and carved work. Examples are the Davison monument at Woodsville, N. H., and the Dr. S. N. Eastman monument at Groton, Vt.

ORANGE COUNTY.

The quarries of Orange County are chiefly in Williamstown, but as these closely adjoin those of Barre, as shown on the map, they will be considered in connection with the Barre quarries. (See p. 141.) A quarry in Topsham and a prospect in Randolph properly belong here.

TOPSHAM.

Granite was formerly quarried at two points in Topsham. One was very near the village of South Ryegate, the other on Pine Mountain about south-southeast of Groton.[62] Hitchcock and Hager's geologic map represents a granite area extending from Groton into Topsham, but it seems too far west.

The **Ricker quarry** is in Topsham at the west foot of Pine Mountain, roughly about 5½ miles west-southwest of Blue Mountain, 2¼ miles southeast of the Benzie quarry, and 2¾ miles south-southeast of Groton and 490 feet above it. (See fig. 22.) Quarry abandoned.

The granite (specimen D, XXIX, $\bar{8}7$, a), "Pine Mountain," is a quartz monzonite of medium bluish-gray color and medium, somewhat even-grained texture with feldspar up to 0.4 inch and mica to 0.1 inch, but with sparse clear porphyritic feldspars including all the other chief constituents. The stone is not quite so bluish as that of the Benzie quarry, in Groton, nor do its feldspars seem to be as evenly distributed. Its constituents are similar. Effervesces with muriatic-acid test.

The porphyritic clear feldspars enhance the brilliancy of the rough surface. Its contrasts are greater than those of the Benzie quarry stone, but there are minute rust spots on the long-exposed blocks about the quarry, the cause of which was not manifest.

The quarry is about 40 by 32 feet, and the working face on the east is 20 feet high from the road and quarry level.

Rock structure: The sheets, 5 to 12 feet thick at their widest parts, are normal and horizontal or inclined 10° N. 45° W. There are two sets of joints—(a), strike N. 70° E., vertical, forms the north wall, and a 25-foot heading north of it with joints 2 to 4 feet apart, and another on the south wall; (b), strike N. 40° E., dip 55° N. 50° W., forms the east wall and recurs 10 feet east. The flow structure has a N. 35° E. course. Vertical pegmatite dikes up to 1.5 inches thick strike N. 25° W. Aplite dikes up to 1 inch thick, strike N. 45° and 55° E.

The product was carted about 3 miles to rail at Groton, 490 feet lower.

RANDOLPH.

Beedle's prospect is in the west corner of the town of Randolph between the Bethel line and the west branch of White River, in school district 11, three-fourths of a mile west and southwest of the Vermont Central Railroad, which here describes a curve. It is on the farm of A. H. Beedle, of Randolph. (See fig. 35.) The foregoing particulars were obtained by G. H. Perkins, State geologist.

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[62] The quarry on Pine Mountain, here described, is probably the one referred to by the State Geologist in 1900 as operated then by the Pine Mountain Granite Co. (See Perkins, G. H., Mineral resources of Vermont, for 1899–1900, p. 75.)

According to the State geologic map of 1861 this granite should be on the west side of the western belt of "clay slate," but no granite is shown on the map in this town.

The granite (specimen D, XXIX, 100, a, and b), fine white granite, is a quartz monzonite of etxremely light gray shade without any mica spots. It is lighter than "Dummerston white" but not as white as that of Bethel when the rough faces are compared, and its slight grayness has a tinge of green in it. Its texture is even grained and fine, with feldspars nearly all under 0.1 inch and none over 0.15 inch. Its constituents, in descending order of abundance, are milk-white striated soda-lime feldspar (albite to oligoclase-albite), some of it intergrown with potash feldspar (microcline), the latter forming, however, but a small portion of the particle (the soda-lime feldspar is more or less kaolinized and micacized); clear colorless quartz with fluidal and other cavities, rarely with hairlike crystals of rutile; very little separate potash feldspar (microcline) in minor particles; and muscovite (white mica) in scales up to 0.37 millimeter. The accessory minerals are zircon, apatite, and rutile. No magnetite or pyrite was detected. Secondary minerals, kaolin, a white mica, rather abundant epidote, and zoisite in irregular particles up to 0.5 millimeter, exceptionally 0.75 millimeter, accounting for the greenish tinge (this is really the fifth mineral in order of abundance); a little calcite and rare chlorite scales up to 0.22, exceptionally 0.75 millimeter, reinforcing the greenish tinge.

An estimate of the mineral percentages made by applying the Rosiwal method to a camera lucida drawing of a thin section enlarged 40 diameters yields these results with a mesh of 1 inch and a total linear length of 34 inches: Feldspar, 76.5; quartz, 21.2; mica, 2.3. The average diameter of the particles obtained from the same calculation is 0.0049 inch; that of the feldspar, 0.0083 inch; of the quartz, 0.0032 inch; and of the mica, 0.0024 inch.

The stone effervesces slightly with muriatic-acid test. W. T. Schaller, a chemist of this Survey, finds that it contains 0.37 per cent of CaO (lime) soluble in warm dilute (10 per cent) acetic acid, which indicates a content of 0.66 per cent of $CaCO_3$ (calcium carbonate, calcite), and this mineral also appears in thin section.

The stone takes a high polish, owing to the absence of all but very minute mica plates. Being a quartz monzonite and also free from mica spots, it will probably hammer quite as white as the quartz monzonite from Bethel. The hand specimens show traces of rift or flow structure.

There are no data as to size of outcrop or as to structure. The principal opening is 60 by 30 feet. There was no quarrying in 1916.

ORLEANS COUNTY.

DERBY.

The **Lacasse quarry,** formerly owned by the Newport Granite Co., is near the center of the town of Derby and about 4 miles roughly east of the city of Newport, on Lake Memphremagog. (See map, Pl. I.) Operator, A. C. Lacasse Granite Co., Newport.

The granite (specimen D, XXIX, 75 a), "Derby gray," is a quartz monzonite, with both biotite and muscovite, of light bluish-gray color and even-grained, medium inclined to fine texture, with feldspars up to 0.25 and 0.3 inch and mica to 0.15 inch. Its constituents, in descending order of abundance, are light smoky quartz with hairlike crystals of rutile, fluidal and other cavities in sheets with cracks parallel to and in places coinciding with them; clear to bluish milk-white striated soda-lime feldspar (oligoclase), mostly much kaolinized and somewhat micacized, also intergrown in places with quartz in

vermicular structure; clear to translucent bluish potash feldspar (microcline and orthoclase), slightly kaolinized; biotite (black mica); and muscovite (white mica). Accessory: Apatite, titanite, allanite, rutile. No magnetite or pyrite was detected. Secondary: Kaolin, a white mica, and calcite from chemical test.

There is no effervescence with dilute muriatic-acid test, but W. T. Schaller, a chemist of this Survey, finds that it contains 0.05 per cent of CaO (lime) soluble in warm dilute (10 per cent) acetic acid, which indicates the presence of nearly 0.09 per cent of $CaCO_3$ (calcium carbonate, calcite), which is slight indeed.

The shade of this stone is between that of "light Barre" and of the granite of Hallowell, Maine. It has more black mica than "light Barre" and stronger contrasts. This stone should hammer lighter than a biotite-muscovite granite.[63]

The quarry, opened about 1880, measured in 1907 about 300 feet N. 45° W. by 250 feet N. 55° E. and averaged 20 feet in depth.

Rock structure: The sheets, 3 to 18 feet thick, dip 20° S. 55° W. They "grow together"—that is, sheet structure is undeveloped in the western part of the quarry—making masses 22 to 25 feet thick. One set of vertical joints, discontinuous, strikes N. 55° W., is spaced 10, 30, and 100 feet, and forms a heading on the north wall. At the northeast corner there is a trace of a transverse set. The rift is reported as horizontal, and the grain as vertical with N. 55° E. course. Both are marked. Flow structure, consisting of muscovitic and biotitic bands, is vertical with N. 50° E. course. The muscovite scales in these bands measure up to 0.25 inch. There are very irregular biotitic surfaces in the eastern part of the quarry, resembling tree roots in form. Associated with them are nonmicaceous lighter tortuous bands. These are presumably irregularities in the flow structure. A "shake structure" up to 5 inches thick occurs on some sheet surfaces, and the rock there is passing into sand. The contact here has been alluded to on page 105. A north-south compressive strain was reported by the foreman. There is no stain on the sheet surfaces.

The product is carted 4 miles to the railroad at Newport. It is used for monuments and buildings. Specimen: The prison-ship martyrs' monument in Fort Greene Park, Brooklyn, N. Y. Height, 150 feet, shaft 18 feet in diameter at base and 14 feet at top.

The **Parmenter quarry** is in Derby Township, near Beebe Plain, close to the Canada line and about a mile east of Lake Memphremagog. (See Pl. I.) Owner, W. H. Parmenter, North Derby. Abandoned in 1920.

The granite (specimen D, XXX, 72, a), a light granite, not examined microscopically, is either a biotite granite or a biotite-quartz monzonite of very light gray color and even-grained medium texture, with feldspars up to 0.3 inch and micas to 0.2 inch. Its constituents are slightly bluish milk-white feldspars, light smoky quartz, and biotite (black mica). It effervesces slightly with acid test.

In general shade this granite is lighter than that of North Jay and darker than that of Bethel, or nearly the same as "West Dummerston white" but with more conspicuous black micas.

The quarry in 1909 was 40 by 25 feet in area and 10 feet deep.

Rock structure: The sheets, 2 to 5 feet thick, are insufficiently exposed but appear to undulate horizontally. Joints (a) strike N. 50° W., dip 60° SW., spaced 10 to over 20 feet; (b) strike N. 30° E., dip 80° S. 60° E., one only. The rift is reported as horizontal, and the grain vertical with N. 50° E. course.

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[63] See a reference to this stone and quarry in Richardson, C. H., The geology of Newport, Troy, and Coventry: Vermont State Geologist Sixth Rept., p. 280, pl. 58, 1908.

In a larger quarry on the Canadian side, a few hundred feet from the other, formerly worked by the same operator, granite of the same mass and character has sheets 10 feet thick and a flow structure with N. 60° W. course.

The product is carted half a mile to a siding on the Canadian Pacific Railway at North Derby and is used for hammered monuments or bases. The quarry was idle in 1916.

BARTON.

In 1913 a specimen was received by this Survey from **Milo J. Owen**, of Barton, as occurring within that township.

The granite (specimen D, XXXV, 109, a) is a medium to dark-gray aplite (p. 42) with a groundmass of fine particles ranging from 0.05 to 0.17 millimeter in diameter and inclosing porphyritic feldspars (milky oligoclase to oligoclase-andesine) from 0.37 to 1.25 millimeters, quartz (smoky?) up to 0.87 millimeter, and biotite (black mica) up to 0.75 millimeter.

As aplites occur in dikes and are a little harder than granite the economic value of this aplite will depend upon the width of the dike, the relative cost of cutting it, and also, of course, the spacing of the joints and sheets.

The **Barnard quarry** is in the township of Barton. Operator, John M. Barnard, R. D. 1, Barton. Quarry idle.

The granite (specimen D, XXXVIII, 26, a), "Barton," is a biotite granite of medium gray shade and of medium texture, with feldspars up to a trifle over 0.2 inch and biotite (black mica) to 0.05 inch.

It does not effervesce with muriatic-acid test. It is a bright granite without marked contrasts.

Its constituents, in descending order of abundance, are clear colorless potash feldspar (microcline), pale smoky quartz with cavities in sheets, clear to milky soda-lime feldspar (oligoclase-albite), somewhat kaolinized, biotite, and very little muscovite. Accessory: Apatite, zircon. Secondary: Kaolin, chlorite, calcite.

The quarry is 300 by 100 feet and up to 9 feet deep.

The product is used for monumental work.

WASHINGTON COUNTY.

BARRE AND WILLIAMSTOWN.

The quarries of Williamstown, in Orange County, will be described in connection with those of Barre, as they belong to the same group and their granite is continuous and identical.

TOPOGRAPHY.

The city of Barre lies about 5 miles southeast of Montpelier (see Pl. I), and the Barre quarries are 3 miles farther southeast, near the southeast corner of the township of Barre, and a few of them are in Williamstown, in Orange County, which adjoins Barre on the south. The city of Barre lies on Stephens Brook, a tributary of the Winooski, which empties into Lake Champlain. About half a mile southeast of Barre this brook receives a tributary from the southeast, known as Jail River. Some 2½ miles southeast of the city this river flows through a canyon-like gorge between flat-topped masses of sand, clay, and boulders over 200 feet thick. A little north of Jail River at this point a roundish granite mass, known as Cobble Hill, rises to a height of 1,000 feet (by aneroid) above the city, and 2 miles about southwest of this hill and a little south of the river another granite mass, known as Millstone Hill, rises to a

height of 1,200 feet above the city. In 1907 56 quarries were grouped about these two granite masses, and of these 52 were about Millstone Hill. The section (fig. 24) will serve to convey a general idea of the surface features described. The locations and designations of the Millstone Hill quarries are given in Plate II.

GENERAL GEOLOGY.

The geology of the granite area of Barre was last treated by George I. Finlay.[64]

His map shows that he regards the two granite hills as parts of one granite area, with a north-northeast trend, over 4 miles long by 1½ miles wide, surrounded by slate and schist. Its representation on the State geologic map of 1861 is not far different. The writer's time was too short to enable him to trace the boundaries of the granite and schist, nor was a map suitable for such purpose available. Finlay represents a schist tongue crossing Millstone Hill diagonally from northwest to southeast and Cobble Hill as all granite, but the writer found schist on the north side of the top of the Cobble, without, however, determining its northern limit. The schist capping also crops out at Jones Bros.' and Barclay's quarries, also near the Marr & Gordon quarry (Nos. 10, 12, 26 in Pl. II), and in Websterville. Some of these schist

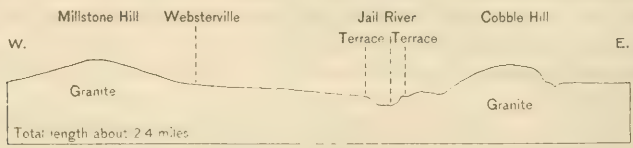

FIGURE 24.—General topographic section through granite mass of Barre, Vt. Scale, about 400 feet to 0.1 inch.

masses are probably lesser bands still lying on the granite, which Finlay states were too small to enter on his small-scale map. The strike of the foliation of the schist about the quarries varies from north to N. 60° E., and the dip is steep west or 90°. In a group of quarries south-southeast of Millstone Hill it strikes uniformly N. 30°–35° E.

These are the chief geologic features of the Barre district. Four formations are represented—(1) the schist, a metamorphosed marine argillaceous and calcareous sediment of unknown thickness, underlying the city and surrounding the granite area; (2) the granite, of igneous origin, intruded in the schist and forming two domes, 2 miles apart, with an intervening depression, which in consequence of the erosion of the schist now project through it; (3) certain dark basic dikes of later date cutting the granite and the schist also; (4) finally, masses of sand, clay, and boulders, over 200 feet thick in the hollow between the domes, of glacial origin, overlying the schist and part of the granite.

The geologic age of schist and granite have been discussed on page 106, and their probable history was sketched on page 107.

As many as seven different sets of surface forms have existed here—(1) the original surface of the sediments of clay and sand before their emergence from the sea; (2) the surface of those sediments after their metamorphism into schist and before the granitic intrusion; (3) the surface of the schist mass as modified by the granitic intrusion; (4) the surface of

[64] The granite area of Barre, Vt.: Vermont State Geologist Third Rept., pp. 46–59, pl. 4, 1902.

the schist and granite masses which resulted from the long period of preglacial erosion; (5) the original surface of the superimposed glacial deposits; (6) the surface of the glacial deposits as modified by glacial-lake levels; (7) the surfaces produced in both unmodified and modified glacial deposits by post-glacial streams. It is assumed in this outline that any modifications of the eroded rock surface by the glacier were unimportant, and the surface of the ice sheet itself has not been considered.

The present surface is evidently of complex origin. Parts of it were formed under (4), (5), (6), and (7). Wherever no glacial deposits were formed or wherever they were afterward removed we have the surface (4). In the gorge between Millstone and Cobble Hills, as shown in figure 24, the coarse and fine glacial deposits have a nearly level surface, which is probably due to terracing by a glacial lake (6). These opposite terraces may have been continuous, but the gorge itself is partly or entirely the result of the cutting of the terraced glacial deposits (7). In places the processes of (7) have exposed the schist surface formed by (5) and made small inroads upon it.

The schist of Barre varies much in character. A few observations were made and specimens collected. In many places it contains lenses and beds of calcareous quartzose rock. On Brook Avenue, in the northwestern part of the city, a mass of this rock dips 30° to 40° about southwest, but with traces of plicated bedding in the opposite direction. It is a very dark gray fine-grained quartzose crystalline limestone. The sections show quartz particles up to 0.24 millimeter in a cement of calcite plates with rare muscovite scales and many minute black (carbonaceous?) particles. At the other end of the city, near the covered bridge over Jail River, it is a very fine black roofing slate with minute secondary plications and spangled with black tabular crystals up to 0.1 inch across, probably of ilmenite. The microscope shows it to be a muscovite-quartz slate with a little biotite and chlorite. Part of the outcrop is a muscovite schist with quartz and calcite and spangled with biotite scales lying across the schistosity; also with rhombic plates of chlorite and ilmenite up to 0.2 inch. Near quarry No. 26 (Pl. II) a granitic dike 3 feet thick crosses the schist. This proves to be a light-gray fine-textured porphyritic biotite granite differing from Barre granite mainly in texture. There are here and there within the granite area strips of schist which are parts of the original capping left by erosion. There are also blocks of schist within the granite (inclusions) which probably dropped into the rising semiliquid granite from the underside of the fractured capping. These are described more fully on pages 64–65.

The pegmatite and aplite dikes which traverse the granite belong to a later stage of the period of intrusion, after the consolidation of the granite. The basic dikes described on page 128 and referred to by Finlay[65] belong to a still later date. He describes as camptonite a 5-foot dike which crosses the schist just south of Barre on the road to South Barre, and he illustrates its spheroidal weathering.

BARRE GRANITE.

Barre granite is known commercially as "dark Barre," "medium Barre," and "light Barre," with some exceptional "very dark Barre" and "white Barre." It appears to be everywhere a biotite granite in which the orthoclase is considerably kaolinized and micacized, but the microcline is fresh. The dark stone of the Milne & Wylie quarry and of the Jones quarry shows so great a contrast between its hammered and polished faces as to indicate that the amount of soda-lime feldspar in it is larger than it is in the other granites of

[65] Op. cit., pp. 49, 50, pl. 6.

Barre or in biotite granites generally, and the thin sections show considerable plagioclase altered like the orthoclase. But Whitman Cross,[66] of this Survey, found a specimen of "dark Barre" quarried by Wells, Lamson & Co. to be a typical biotite-muscovite granite in which the amount of plagioclase (soda-lime feldspar) was so small as to place it among the accessory constituents. (See p. 138.)

The various shade and color designations of this granite are due in part to the different degree of kaolinization and micacization of its orthoclase feldspar, causing it to range from a translucent bluish gray to milk-white, and in part also to the varying content of black mica. Technically its colors are here defined as (1) very light gray (Wheaton quarry, abandoned), equivalent to that of North Jay, Maine; (2) light inclining to medium, slightly bluish gray (Jones light quarry), between that of North Jay and of Hallowell, Maine; (3) light medium bluish gray (Smith upper quarry), between that of Hallowell, Maine, and Concord, N. H.; (4) medium bluish gray (Duffee quarry), a trifle darker than "Concord granite"; (5) dark inclining to medium bluish gray (Bruce quarry); (6) dark bluish gray (Marr & Gordon quarry); (7) very dark bluish gray (Marr & Gordon quarry knots), equivalent to "dark Quincy." The chief product consists of (3), (4), and (5). The dark shades occur near the Williamstown line, the light near the top of Millstone Hill on its south and southwest sides, and also about three-fifths of a mile south-southwest of the top. The cause of this distribution is not evident.

Its texture ranges from fine to medium—that is, with feldspars up to 0.2 and 0.4 inch, generally, however, not exceeding 0.2 inch, few reaching 0.3 inch—so that it may be generally designated fine inclining to medium or medium inclining to fine. But the light granites of the Millstone quarry, on Millstone Hill, and of the Wheaton quarry, on Cobble Hill, are of medium texture, with feldspars to 0.4 inch. Its mica particles range up to 0.1 and 0.2 inch, but in the "very dark" to 0.3 inch.

Its constituents, in descending order of abundance, are (*a*) clear colorless or bluish to translucent and milk-white potash feldspar (orthoclase, kaolinized, and micacized, and less of clear microcline) rarely intergrown with a little soda-lime feldspar; (*b*) light smoky quartz, showing optical effects of strain, rarely with rutile needles, generally with fluidal and other cavities in sheets, and with rift cracks parallel to or coinciding with them, and in some sections with another set of fewer and shorter sheets of such cavities at right angles to the other and with grain cracks parallel to them (in one place the rift cracks extend into the feldspar and are there filled with fibrous muscovite);[67] (*c*) translucent to milk-white soda-lime feldspar (oligoclase-albite to oligoclase and oligoclase-andesine), some of it with flexed twining lamellae, more or less kaolinized and micacized, and in places with calcite; (*d*) biotite (black mica), some of it chloritized; (*e*) a little muscovite or bleached biotite. Accessory minerals, pyrite, magnetite, titanite, allanite, apatite, zircon, rutile. Secondary, calcite (abundant within the orthoclase), one or two white micas, epidote, and chlorite. Minute veinlets of quartz, of calcite, and of epidote occur exceptionally.

An estimate of the mineral percentages made by the Rosiwal method on a piece of "dark" yielded these results: Feldspar, 65.522; quartz, 26.578; mica, 7.900.

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[66] See U. S. Geol. Survey Nineteenth Ann. Rept., pt. 6, continued, p. 224, 1898.

[67] Finlay (op. cit., p. 54) describes these rift cracks as crossing from one quartz crystal particle to another without interruption and as containing arborescent crystalline growths, possibly of manganese dioxide.

All the Barre granites effervesce with muriatic-acid test. W. T. Schaller, chemist, of this Survey, finds that the "light Barre" contains 0.49 per cent of CaO (lime), soluble in warm dilute (10 per cent) acetic acid, and the dark 0.63 per cent, indicating a content of 0.87 and 1.12 per cent of $CaCO_3$ (calcium carbonate, calcite), respectively; the presence of this mineral is also shown by the microscope.

Finlay's analysis of the darker granite from the area south of Millstone Hill is given here for reference.[68]

Analysis of "dark Barre" granite.

Silica (SiO_2)	69.89
Alumina (Al_2O_3)	15.08
Iron sesquioxide (Fe_2O_3)	1.04
Iron oxide (FeO)	1.46
Magnesia (MgO)	.66
Lime (CaO)	2.07
Soda (Na_2O)	4.73
Potash (K_2O)	4.29
Water uncombined (H_2O at 110°)	.31
Water combined (H_2O ignition)	.23
Phosphorus pentoxide (P_2O_5)	Trace.
	99.76

W. C. Day found the specific gravity of "dark Barre" and "medium Barre" to be 2.662 to 2.672, and its crushing strength to range from 14,968 to 19,957 pounds to the square inch. (See p. 139.) L. P. Kinnicutt in 1908 found that 100 pounds of Barre granite absorbs 0.294 pound of water. (See p. 157.)

Barre granite is mostly monumental, but some is building granite. The light, medium, and dark monumental stone, although brilliant in the rough, has weak mineral contrasts, but these are stronger on the polished face of the dark. The white of the more kaolinized and micacized orthoclase feldspars and the black of the mica, and the combined bluish gray of some of the feldspar and smoke color of the quartz form three distinct shades, but owing to the fineness of the texture these merge a few feet away, and the white alone shows against a dark-gray ground. "Light Barre" granite is never polished but is hammered, because of the feeble contrast between the polished and cut surface, but the dark is often used for polished work. Its polish is fair, and the contrast between the polished and cut face is more marked along the hard way than in the rift or grain directions. In the stone from the Milne & Wylie and Jones dark quarries this contrast is so marked as to imply the presence of considerable soda-lime feldspar, for the contrast is almost as great as in a quartz monzonite. The polished face shows pyrite and a little magnetite.

GEOLOGY OF BARRE QUARRIES.

The granite was observed in contact with the schist at six quarries (Pl. II, Nos. 6, 8, 9, 10, 12, 20). The results of a study of the contact phenomena at two of these quarries are given on pages 85–88.

The schist inclusions have already been dwelt upon (pp. 64–65). At two quarries (Pl. II, Nos. 6, 32) these inclusions and the schist capping have been penetrated by minute dikes of granite and pegmatite proceeding from the granite. At one of these quarries the granite is darkened for a space of 7 feet from the inclusion.

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[68] Op. cit., pp. 55, 56.

The sheet structure of Millstone Hill appears to form a more or less unsymmetrical flattish dome. The central part of this dome is exposed at the Wetmore & Morse quarry (Pl. II, No. 14), where the sheets dip from the horizontal both eastward and westward 10°. West-southwest of that point and lower down, at the Smith upper quarry (Pl. II, No. 15), they dip 10°–15° SW., and so also in the Duffee quarry; still farther down, at the Smith lower quarry (Pl. II, No. 17), they dip 20°–30° SW. On the northeast side at the Bond & Whitcomb quarry (Pl. II, No. 19), the sheets dip low to the northeast, and at the next quarry (Pl. II, No. 26) 15° E.; at the Canton quarry (No. 21) 10° N., but at the Barney quarry (No. 20) 10° NE. and NW. At the Walker quarry (No. 23) low east and northeast. An east-northeast to west-northwest section of the hill passing through the quarries named would thus give a general low anticlinal. The sheets of Cobble Hill also form a dome, for at the Wheaton quarry, north-northwest of the top, they dip 10° NW. and NNE., but on the southwest side of the hill, at the Wildbur quarry, they dip 60° S. 75° W., and at the Bianchi quarry, farther south, 35° S. 50° W. But the sheet structure half a mile southeast of Millstone Hill (Jones and Consolidated quarries) and toward the Williamstown line is too complex to unravel. The sheets are lenticular and normal at only 21 out of the 41 quarries visited. These 21 quarries include, besides those named above, the small group of quarries in the northwest corner of the area mapped (Pl. II), also the Milne & Wylie, Anderson, and Wells-Lamson quarries, and the Pirie, in Williamstown. In the remaining 20 quarries the sheets are more or less irregular or absent. In some places the lenses are very short and thick; in others, as in the large Jones Bros. quarry, there are only traces of sheets. In several quarries, as the Manufacturers and Anderson quarries, the sheets "grow on"—that is, the sheet partings stop laterally, leaving the center or half of the quarry without sheets. Figure 27 shows close joints without sheets in one part of the quarry, and sheets without joints in the adjoining part. In several quarries sheet structure stops vertically at depths of 20, 25, or 35 feet from the rock surface—for example, at the Barclay, Capital, and Milne quarries. At the Smith lower quarry there is a mass 58 feet thick without sheets; at the Bruce, one such of 48 feet; at another, of 40 feet; and at the Marr & Gordon, of 80 feet. At one of the Boutwell quarries there is a lens ("boulder") about 33 feet thick estimated to contain about 500,000 cubic feet. At some quarries there is no trace of sheet structure. This incomplete development of sheet structure is the chief difficulty in quarrying at Barre. Wherever low-dipping joints occur these are utilized as sheets, but where such joints are wanting horizontal channeling has to be resorted to, which is expensive. The sheets range from 6 inches to 30 feet in thickness. At the Wells-Lamson quarry the "toe-nail" structure intersects the sheets. At one quarry a sheet surface is slickensided.

During the last 10 years the depth of some of the quarries has greatly increased. The bottom of some of the Boutwell, Milne & Varnum Co.'s quarries is 200 feet below the rock surface. In some places the limit of sheet structure seems to have been almost reached.

There are ten sets of joints—(a), strike N. 5° W. to N. 10° E.; (b) N. 15°–20° E.; (c) N. 30°–40° E.; (d) N. 45°–55° E.; (e) N. 60°–70° E.; (f) N. 75°–90° E.; (g) N. 60°–80° W.; (h) N. 45°–50° W.; (i) N. 30°–40° W.; (j) N. 10°–25° W. Of these (c) occurs at 21 and (f) at 18 quarries. The next most frequent are (e) and (i), each at 10 quarries, and (j) at 8. These joints divide themselves into five complementary sets—that is, sets at right angles to one another and presumably due to the same strain. These sets consist of (a) and (f), (b) and (g), (c) and (h), (d) and (i), and (e) and (j). The spacing of the joints ranges from 1 to 200 feet. In 26 quarries

the spacing ranges from a minimum of 1 to 8 feet to a maximum of 20 to 50 feet; in 18 quarries from a minimum of 10 to a maximum of 100 to 200 feet. Many of the joints are intermittent or discontinuous. Abnormal relations of joints and sheets are shown in figure 28. In some quarries joints of the same strike incline in opposite directions, as shown in figure 26.

Some joints are coated with limonite and calcite; others with a greenish, usually slickensided film of muscovite, secondary quartz, and chlorite. Back of it the feldspars are microscopically brecciated and cemented with fibrous muscovite, also minutely veined with calcite and quartz. These veins run at right angles to the face. Some joint faces are very uneven, and their minor protuberances are slickensided. Other joint faces are coated with somewhat large muscovite scales. The slickensides of joints usually have their furrows pointing in the direction of the dip of the joint, indicating motion up or down along the dip.

Headings are numerous and usually rusty. On the northwest wall of the Marr & Gordon quarry the central part (25 feet) of a heading striking N. 35° E. branches off to the northwest; and at another quarry (p. 143) a heading undulates back and forth laterally.

Flow structure is rarely observable. At the Wells-Lamson quarry (Pl. II, No. 24) a 12-inch band of darker granite shows the flow to have been N. 70° E., with an inclination of 60° N. 20° W. On Cobble Hill (Bianchi quarry) it is about north and vertical. At the Barney quarry for a space of 15 feet from the contact with schist the granite is coarse and fine in alternating bands.

Segregations are uncommon. At the Sanguinetti quarry (Pl. II, No. 18) the granite is concentrically banded in a pear-shaped mass, 1 and 2 feet in its diameters. Biotitic knots are rare and small. One 1.5 by 0.5 inch was noted. Possibly the darker, more biotitic, irregular roundish portions of the granite near the schist contacts at the Marr & Gordon and Jones dark quarries (pp. 130, 141) are of the nature of the segregations.

The rift as reported by foremen is everywhere vertical, and the grain in all but two quarries is horizontal. The course of the rift about Millstone Hill and in Williamstown appears to range from N. 30° E. to N. 60° E., and on Cobble Hill from N. 50° E. to N. 75° E. In the group of quarries about the Boutwell and Bruce quarries and the adjoining ones in Williamstown the rift is N. 50°–60° E., but near the top of Millstone Hill (Duffee, Millstone) it is N. 30°–40° E. At the Capital and Barre quarries (Pl. II, Nos. 29, 33) it is reported as varying in different blocks. At the Anderson quarry (No. 8) it is reported as N. 60° E., and the grain, here better than rift, as dipping 20° N.; but at the Jones light quarry, only 1,500 feet away, the rift is reported as N. 35° E. and the grain as horizontal. At the Pirie quarry the grain is reported as dipping 35° N.

Pegmatite dikes are not abundant. One at the Pirie quarry is described on page 49; those at the Anderson quarry on page 85 (fig. 10), and those at the Bailey quarry on page 49.

Aplite occurs in irregular veinlike masses in contact with schist inclusions at two quarries. Specimen D, XXIX, 14, a, from the Jones dark quarry, is of light medium bluish to greenish gray color and of very fine texture, with mica up to 0.05 inch, its other minerals not distinguishable. In thin section it consists of microcline, kaolinized albite to oligoclase-albite, and quartz with a little biotite, some of it chloritized, and still less muscovite or bleached biotite. It contains allanite and carbonate. Specimen 44, c, from the Bailey quarry, is of light medium purplish gray color and of porphyritic texture. It

consists of light purplish-gray to milk-white feldspar, clear quartz, and black mica. The particles of the matrix are from 0.025 to 0.1 millimeter in diameter. The porphyritic crystals (mostly oligoclase-albite, some with zonally arranged quartz, rarely microcline) measure from 0.25 to 1 by 0.5 millimeter. Pyrite is accessory.

Quartz veins from 0.05 to 2 inches wide of pegmatitic origin are more abundant. One at the Milne quarry is described on page 51.

Basic dikes were noted at seven quarries. At three (Jones light, Capital, and McIver & Matheson) the exposures may all belong to one dike, which would thus be half a mile long; and as two others (Barney and Walker quarries) are clearly the same dike, thus 800 feet long, only four dikes were actually observed. The long one is from 2 feet 6 inches to 9 feet thick, with a N. 40°–45° E. course and vertical. The other, from 1 to 2 feet thick, has a N. 35°–40° E. course. One at the Millstone quarry, up to 2 feet thick, has a N. 25° W. course and weathers spheroidally. One at the Bianchi quarry, on Cobble Hill, is 6 inches thick, with a N. 55° E. course. Two of these dikes were examined in thin section. The dike rock of the Jones light quarry is a dark-greenish diabase of very fine texture (labradorite, augite, magnetite, apatite needles, secondary calcite). Its augite is altered to a chlorite-like mineral giving the greenish color. The Millstone dike rock appears to be an altered camptonite of very dark gray color and porphyritic texture, with very fine matrix (plagioclase, micacized, kaolinized, and with calcite, magnetite in crystals, and skeleton crystals). The porphyritic crystals or masses appear to be hornblende more or less altered to chlorite and calcite; one is replaced by quartz.

At three quarries the granite within 1 to 2 feet of these dikes is crossed by vertical subjoints 1 to 6 inches apart parallel to the dike wall; and the granite scales off along them. These subjoints are to be regarded as the effect either of the heat of the dike or of the strain which accompanied its intrusion.

A north-south compressive strain is reported at the Bruce and Wells-Lamson quarries, and an east-west one at the Canton quarry.

Rusty stain along sheet surfaces varies greatly in amount. In many quarries it does not exceed 6 inches in thickness; in others it reaches 12, 16, and 18, and in one place 24 inches, but that was confined to the upper sheets. Generally it is confined to the lower surfaces of sheets. On joint faces it is from 6 to 24 inches and abounds on headings.

In concluding this part of the subject attention is recalled to the evidence of minor mineral and structural changes brought out in this and the previous section. The rift and grain cracks in the quartz, the straining of the quartz as shown by its optical behavior, the bending of the twinning lamellae of the soda-lime feldspars, the formation of minute veins of secondary quartz, calcite, and epidote, the brecciation of feldspars and the formation of fibrous muscovite and of chlorite and of little veins of quartz and calcite in consequence of motion along joint planes, the formation of subjoints near basic dikes—all these facts point to crustal movements of different dates, some probably preceding the sheet and joint structure, others subsequent to it.

QUARRIES.

The **Boutwell quarry** is about south of the top of Millstone Hill, in Barre. (See Pl. II, No. 1.) Operator, Boutwell, Milne & Varnum Co., Montpelier.

The granite, chiefly "dark Barre" (but also some "dark medium" and "medium"), is a biotite granite of dark inclining to medium bluish-gray color and of fine, even-grained texture, with feldspars up to 0.2 inch and mica to 0.1 inch. Its color, texture, constituents, and qualities correspond to those of the "dark" of the Bruce quarry, described on page 131.

The quarry, opened about 1886, is somewhat T-shaped, measuring about 600 feet in a N. 80° E. direction by 60 feet north and south at the east end and 120 feet at the west end, with a 150-foot square extension on the north side, but only 150 feet from the west end. Its depth in 1907 was from 50 to 100 feet.

Rock structure: The sheets are irregular, 4 to 30 feet thick, striking N. 30° E. and also east-west and dipping 10°, 20°, and 35° N. 30° W. and north. Joint, rift, and dike courses are given in figure 25.

Joints (A) dip 55°–70° S. 10° W., are spaced 5 to 50 feet, and form the north and south walls of the main part. They are mostly limonitic or slickensided with a lustrous greenish coating, described on page 127. Joints (B) are vertical, discontinuous, only a few feet long, form small headings, and are coated with calcite and limonite to 0.25 inch. One at the southeast corner dips 60° N. 40° W. (C) dips 10° S., exceptional, only a few feet long, with lustrous coating, as under (A). The rift is reported as vertical, and the grain as horizontal. Three large schist inclusions measure respectively 55 by 10 by over 6 feet, 20 by 4 by 3 feet, and 10 by 8 feet. The first has been described on page 64. A minute vein (a) of muscovite and quartz dips 50° E. The granite parts along it. Vein (b) is scarcely 0.05 inch wide, but has a border of dark bluish green (chloritic) or brown (limonitic), 0.25 inch wide on either side. (See further p. 74.) The "sap" is from 8 to 12 inches thick on the lower surfaces of sheets and is conspicuous in the headings.

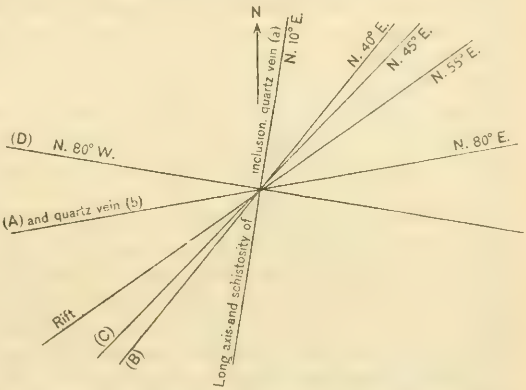

FIGURE 25.—Structure at Boutwell quarry, Barre, Vt.

Product: As the stone is sold by the company in rough blocks, there are no records of the monuments made of its blocks. The monolithic Smith obelisk at Sharon, Vt., came from this quarry.

The **Milne & Wylie quarry** adjoins the Bruce quarry on the south and lies about south of the top of Millstone Hill, in Barre. (See Pl. II, No. 3.) Operator, Boutwell, Milne & Varnum Co., Montpelier.

The granite (specimens D, XXIX, 11, a, b, c), "dark Barre," is a biotite granite of dark bluish-gray color, a trifle darker than that of the Bruce quarry, and of even-grained fine inclining to medium texture, with feldspars up to 0.3 inch and mica to 0.12 inch. Its constituents are the same as those of the Bruce and Marr & Gordon quarry stone described on pages 130, 131, but it contains considerable soda-lime feldspar, more or less kaolinized and micacized and with calcite. Its strong contrasts of shade between cut and polished faces also indicate the presence of an unusual amount of soda-lime feldspar for a biotite granite. It effervesces with muriatic-acid test.

An estimate of the mineral percentages by the Rosiwal method yields the following results with a mesh of 0.2 inch and a total linear length of 66.6 inches: Feldspar, 65.522; quartz, 26.578; mica, 7.900. The average size of all the particles obtained from the same measurements, adding 50 per cent to the

number of feldspar particles for the unseparated second feldspar, proves to be 0.069 inch, that of the feldspar 0.074 inch, the quartz 0.079 inch, and the mica 0.033 inch.

The polished face shows a little pyrite and less magnetite. The cut or hammered hard-way face is as light as the cut face of the Jones "light Barre," thus affording a very marked contrast with the polished face. The mineral contrasts are weak in the rough stone, but stronger on the polished face, white, black, bluish-gray, and smoke color being easily distinguished in it within a distance of 2 feet. The polish is fair.

The quarry, opened about 1887, was in 1907 about 400 feet from east to west by 200 feet across, but with a mass 100 by 50 feet projecting into the quarry from the east wall.

Rock structure: The sheets, 3 to 30 feet thick, dip 20°–30° NW. Joints, one set only, strike nearly east, dip 60°–70° S., form the north and south walls and a heading which constitutes the projecting mass on the east wall. These joints, being spaced 3 to 20 feet, cut up the sheets.

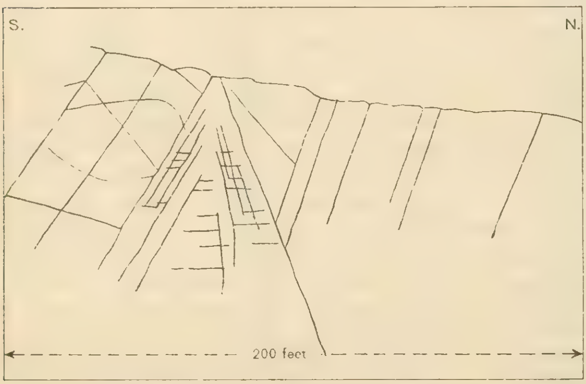

FIGURE 26.—Structure on west wall of Empire dark quarry, Barre, Vt.

The **Empire dark quarry** is southwest of the Milne & Wylie quarry and about south-southwest of the top of Millstone Hill, in Barre, just north of the Williamstown line. (See Pl. II, No. 4.) Operator, Boutwell, Milne & Varnum Co., Montpelier.

The granite is like that from the Bruce quarry, described on page 131.

The quarry, opened about 1888, is about 375 feet in a N. 75° E. direction by 200 feet across and in 1907 was from 75 to 120 feet in depth.

Rock structure: The sheets, 3 to 18 feet thick, are somewhat irregular, dipping low, rarely 40°–45° N. There are two sets of joints—(a), strike N. 65°–70° E., dip 65°–70° S. 15° E., spaced 4 to 25 feet, forms a heading on the north wall, a 10-foot one on the south wall, and a 25-foot one in the middle. This set exceptionally dips 65°–70° N. 15° W., forming with the rest a V-shaped heading in the center of the quarry, as shown in figure 26. The faces of (a) are coated with limonite and bordered with its stain. The other set (b) is exceptional, strike N. 15° W., vertical. The rift and grain are as at adjoining quarries. There are three schist inclusions on the east wall, the largest 20 by 10 feet.

The **Marr & Gordon quarry** is east-southeast of the Empire quarry and about south-southwest of the top of Millstone Hill, in Barre, just north of the Williamstown line. (See Pl. II, No. 5.) Operator, Boutwell, Milne & Varnum Co., Montpelier.

The granite (specimens D, XXIX, 8, b, bb, d), "dark Barre" (derrick 9), is a biotite granite of dark bluish-gray color and of even-grained fine texture, with feldspars up to 0.2 inch and mica to 0.1 inch. Its constituents, in descending order of abundance, are clear bluish to translucent and milk-white potash feldspar (orthoclase, kaolinized and micacized, with a little clear microcline), some of it with minutely intergrown soda-lime feldspar; light smoky quartz, with

cavities in sheets and showing marked optical effects of strain; translucent to milk-white soda-lime feldspar (oligoclase to oligoclase-andesine) rarely with curved twinning lamellæ, more or less altered; biotite (black mica), rarely chloritized; very little muscovite or bleached biotite. Accessory: Pyrite, magnetite, zircon, titanite, apatite. Secondary: Calcite (in orthoclase), kaolin, one or two white micas, and chlorite.

The stone effervesces with muriatic-acid test. W. T. Schaller, a chemist of this Survey, finds that it contains 0.63 per cent of CaO (lime) soluble in warm dilute (10 per cent) acetic acid, which indicates a content of 1.12 per cent of $CaCO_3$ (calcium carbonate, calcite); the presence of this mineral is also shown by the microscope.

This granite is regarded by the firm as harder and darker than the "dark" from its other quarries. It resembles that of the Milne & Wylie quarry (p. 129) but when polished shows somewhat higher mineral contrasts. It takes a fair polish. The polished face shows some pyrite and magnetite.

At the west end of the quarry, near the contact of granite and schist, is a mass (so-called knot) of still darker granite of sufficient size for commercial use. This "very dark Barre" (specimen D, XXIX, 8, a) is a biotite granite of very dark bluish-gray color, much darker than the "dark" and as dark as "dark Quincy" (p. 321) and of fine inclining to medium, even-grained texture, with feldspars up to 0.2 inch and mica to 0.3 inch. Its constituents are the same as those of "dark Barre," specimen 8, b, etc., but the biotite is much more abundant. The second feldspar is oligoclase-albite. The stone effervesces with muriatic-acid test.

Rock structure: In the main opening the sheets are unusually irregular. At the east end they are 18 to 20 feet thick, but in the northwestern part for a depth of 80 feet there are none. In the small opening the sheets are more regular and from 4 to 14 feet thick. There is but one set of joints, strike N. 35° E. and vertical, forming a 20 to 25 foot heading on the northwest wall, also the northwest wall of the smaller opening, where it recurs at intervals of 3 to 10 feet. The heading in the main quarry branches off diagonally to the northwest, forming a band 20 to 30 feet wide, about halfway down the quarry. This unusual structure indicates complex strains. At the top of the west end the granite is in contact with a quartz-biotite schist spangled with biotite scales. The two rocks are firmly welded together in places across the foliation of the schist. Near this schist the granite is much darker from more abundant and larger biotite scales. (See p. 25.) The outline of the darker stone is irregular. The rift is reported as vertical, with N. 55° E. course, and the grain as horizontal.

The **Bruce quarry** adjoins the Boutwell on the southwest and lies about south of the top of Millstone Hill, in Barre. (See Pl. II, No. 2). Operator, Boutwell, Milne & Varnum Co., Montpelier.

The granite (specimen D, XXIX, 12, a), "dark Barre," is a biotite granite of dark inclining to medium bluish-gray color, and of even-grained fine texture, with feldspar up to 0.2 inch and mica to 0.1 inch. Its constituents, in descending order of abundance, are translucent bluish-gray to milk-white potash feldspar (orthoclase, kaolinized and micacized, and a little clear microcline, one such orthoclase inclosing a fresh microcline); light smoky quartz, with cavities in sheets and with cracks parallel to them (the quartz shows optical effects of strain); milk-white soda-lime feldspar (oligoclase-albite), more or less altered, rarely with bent twinning planes; biotite (black mica); and a little muscovite or bleached biotite. Accessory: Titanite, magnetite, pyrite. Secondary: Not a little calcite within the orthoclase, kaolin, one or two white micas. The stone effervesces slightly with muriatic-acid test.

Its mineral contrasts are feeble owing to fineness of texture and the lightness of quartz. There is some contrast between the polished and cut faces along the hard way.

The quarry, opened in 1890, measured in 1907 about 250 feet in a N. 80° E. direction by 125 feet across and 60 to 100 feet in depth.

Rock structure: The sheets, 4 to 10 feet thick, dip 5°–10° N. At the bottom is a mass 48 feet thick without sheets. There are three sets of joints—(a), strike N. 80° E., with varying dip, forms the south wall and an 8-foot heading on the north wall, spacing 10–20 feet, but makes wedge-shaped masses owing to varying dip; (b), diagonal, "slide," strike N. 40° E., vertical, at northwest corner, with uneven slickensided face; (c), strike N. 20° W., dip 70° N. 70° E., one in center. The rift and grain are as at Boutwell quarry. A heavy north-south compressive strain is reported.

The **Bailey quarry** is southeast of the Milne & Wylie quarry and about south of the top of Millstone Hill, in Barre. (See Pl. II, No. 6.) Idle but owned by the Boutwell Co.

The granite, "dark Barre," is a biotite granite of dark color and fine even-grained texture, similar to that of the Bruce and Milne & Wylie quarries.

The quarry in 1907 was about 135 by 75 feet and from 10 to 35 feet in depth.

Rock structure: The sheets are imperfectly developed. There are two sets of joints—(a), strike N. 20° W., dip 70° N. 70° E., spaced 3 to 20 feet; (b), strike N. 60° E., dip 75° S. 30° E., spaced 2 to 6 feet, occurs on the west side only. There the granite is in contact with schist which has a foliation strike of N. 60° E., dip of 35° N. 30° W.; also one of N. 20° E., with vertical dip. At the northwest corner is a schist inclusion 26 by 5 feet, with a foliation striking N. 85° W. and a dip of 55° N. Dikes large and minute of pegmatite and aplite penetrate the schist capping and the inclusion rendering the relations intricate. Some of the details are given on page 87.

The **Anderson quarry** is about S. 10° E. of the top of Millstone Hill, in Barre, 1,800 feet northeast of the Williamstown line. (See Pl. II, No. 8.) Abandoned but described on account of its great geologic interest.

The granite is a biotite granite of gray shade and fine even-grained texture.

The quarry, opened about 1892, measured in 1907 about 200 feet in a N. 45° W. direction by 150 feet across and from 50 to 75 feet in depth.

Rock structure: The granite on the southeast and northeast sides and on the west of the south corner is capped by schist and slate up to 15 feet thick, with a cleavage and schistosity striking N. 30° E. and dipping 55° N. 40° W. The relations of granite and slate are shown in Figures 10 and 11, and the contact phenomena have been given on page 85. The sheets, 1 to 15 feet thick, dip 20° NW. There are three sets of joints—(a), strike N. 50° W., dip 75° N. 50° E., occurs on the southwest side only; (b), strike N. 5° E., dip 70° E., spaced 6 to 15 feet; (c), strike N. 60° E., dip 75°, spaced 3, 15, and over 25 feet. The rift is reported as vertical, with N. 60° E. course; the grain as dipping with the sheets 20° NW., and as easier than the rift. A 1-foot pegmatite dike borders one of the schist masses, as shown in figure 10. At the east side there are two schist inclusions, measuring 10 by 2 to 3 feet and 6 by 2 feet, respectively, besides minor fragments.

The **Stephen & Gerard quarry** is 600 feet north of the Anderson quarry and south to south-southeast of the top of Millstone Hill, in Barre. (See Pl. II, No. 9.) Operator, Standard Granite Co., Barre.

The granite, reported by the firm as "medium Barre," is a biotite granite of gray shade and of even-grained, fine texture. For descriptions of "medium

Barre" see page 124. The quarry in 1907 measured about 175 feet in a N. 30° E. direction by 150 feet across and from 20 to 50 feet in depth.

Rock structure: The sheets are undeveloped in the west half of the quarry, but closely spaced joints there serve the quarrymen instead. Rift and joint courses are shown in figure 27 and the complex relations on the north wall in figure 28. There are four sets of joints—(A), dip 35° S. 40° E., spaced 3 to 17 feet; (B), vertical, spaced 30, 40, to 90 feet, forms the south wall; (C), diagonal, dip 35° E., one only in east half; (D), vertical, forms heading on south wall. The granite is in contact on the west side and southeast corner with schist which has a foliation striking N. 30° E. and dipping 50° N. 60° W. Rusty stain is from 1 to 6 inches thick on sheet and joint faces.

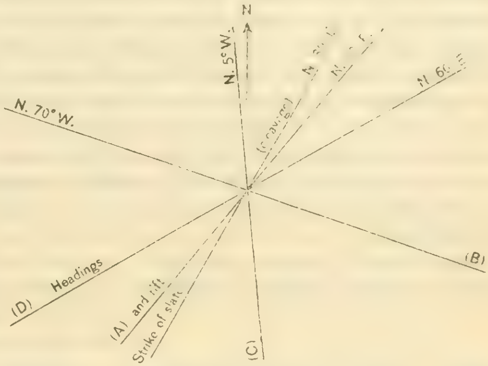

Figure 27.—General structure at Stephen & Gerrard quarry, Barre, Vt.

The **Barre Granite & Quarry Co.'s quarry** is about 500 feet north of the Canton quarry, and in about that direction from the top of Millstone Hill, in Barre. (See Pl. II, No. 22.) Operators, E. L. Smith & Co., Barre.

The granite, "light Barre," is a biotite granite of light-gray shade like that previously described.

The quarry, opened in 1904, was estimated in 1907 as measuring about 300 feet in a N. 22° E. direction by 150 feet across, and in 1918 was 100 feet deep.

Rock structure: The sheets, 1 to 8 feet thick, are normal and dip very low southeast. There are two sets of joints—(a), strike N. 15° E., vertical, dip 55° E. on the southeast and northeast walls, spaced 10, 20, to 100 feet; (b), strike N. 30°–35° W., dip 75° N., 60° E. and vertical, discontinuous, one on and one near the south wall. The rift is reported as vertical with N. 30° E. course, and the grain as horizontal.

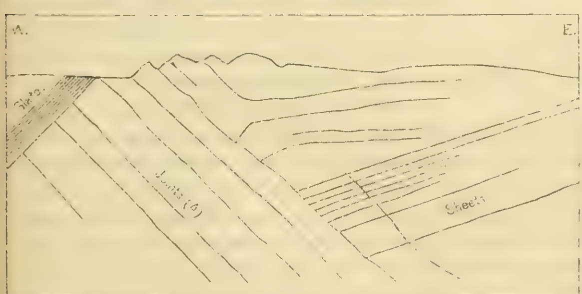

Figure 28.—Structure on north wall of Stephen & Gerrard quarry, Barre, Vt.

The product is used for monuments and buildings. The stone for the Vermont capitol at Montpelier came largely from this quarry.

The **Jones Light quarry** is about south-southeast of the top of Millstone Hill, in Barre. (See Pl. II, Nos. 10 and 11.) Operator, Jones Bros. Co., Barre, Vt., and Boston, Mass.

The granite (specimen D, XXIX, 27, b), "light Barre," is a biotite granite of light, very slightly bluish-gray color. Its position among the light granites is between that of North Jay, Maine, which is very light gray, and that of

Hallowell, Maine, which is light, inclining to medium. Its texture is even grained, fine inclining to medium, with feldspar up to 0.2 inch, rarely 0.3 inch, and mica to 0.1 inch. Its constituents, in descending order of abundance, are clear colorless to bluish translucent and milk-white potash feldspar (orthoclase, kaolinized and micacized, with fresh microcline); very light smoky quartz with sheets of cavities with brightly polarizing rift or grain cracks parallel to or coinciding with them; translucent to milk-white soda-lime feldspar (oligoclase-albite, more or less altered), rarely with bent twinning planes; biotite (black mica), some of it chloritized; very little muscovite or bleached biotite. Accessory: Magnetite (very little) and zircon. Secondary: Calcite, usually in the orthoclase, kaolin, one or two white micas, and chlorite.

The stone effervesces with muriatic-acid test. W. T. Schaller, chemist, of this Survey, finds that it contains 0.49 per cent of CaO (lime) soluble in warm dilute (10 per cent) acetic acid, which indicates a content of 0.87 per cent of $CaCO_3$ (calcium carbonate, calcite), the presence of which is also shown in thin section.

The mineral contrasts are feeble, and so are those between cut and polished faces. The stone is used for rough, hammered, and carved monumental work.

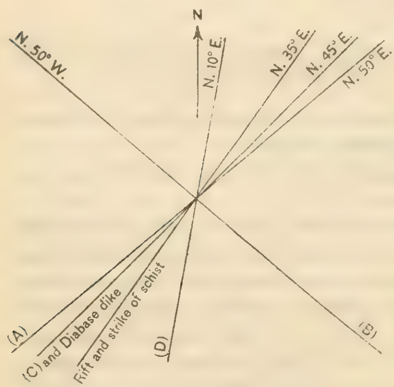

FIGURE 29.—Structure at Jones Light quarry, Barre, Vt.

The quarry consists of two openings. The main and older one in 1907 measured over 550 feet in a N. 35° E. direction by 60 to 200 feet across, and in 1918 was 125 feet deep. A later one, 300 feet N. 30° E. from the north end of the other, was about 200 feet square and 50 feet deep.

Rock structure: Joint, rift, and dike courses are shown in figure 29. Sheet structure is hardly developed or very irregular. Traces of sheets dip 10° W. On account of this much horizontal channeling has to be done. There are six sets of joints—(A), diagonal and vertical; (B), also vertical, spaced 20 to 30, 50 feet and over; (C), dip 45° S. 45° E., discontinuous, occurs here and there in north part of quarry; (D), dip 45° W., undulating, occurs with (C); (E), in new opening, dip 45° N. 65° E., spaced 3 to 50 feet, forms a heading at northwest corner; (F), in new opening, dip steeply N. 58° E. There is a schist capping on the west wall of the main opening 10 to 20 feet and more thick, and on part of east wall, and also forming the east wall of new opening. Its foliation strikes N. 35° E. and dips steeply to 90°. The schist is said to continue indefinitely on the east and also to be at least 150 feet wide on the west. Rift is vertical and good, the grain horizontal. A vertical diabase dike, 8 feet thick, crosses the north half of the main quarry diagonally, and also the schist capping. (See, further, p. 128.) Thirty feet below the granite surface is a schist inclusion 30 feet long and up to 3 feet thick, tapering.

The product is used for rough and hammered face and carved monuments. The following specimen monuments combine the product of this quarry with that of the firm's dark quarry described on page 141: Soldiers and sailors' monument, Angola, Ind.; Ohio and Iowa State soldiers' monuments, Chattanooga, Tenn.; Governor Curtin monument, Bellefonte, Pa.; State soldiers' monument, York, Pa.; Hearn monument, with monolithic spire 53 by 4 by 4 feet, Woodlawn, N. Y.; Rouse mausoleum, Winchester, Va.; Krueger mausoleum, Newark,

N. J.; Gary mausoleum, with roof stones of the "light," 35 by 9 feet 6 inches by 1 foot 6 inches each, Wheaton, Ill.; Goodall monument, Sanford, Maine.

The **Wetmore & Morse quarry,** 1,007 feet above the city, lies in a saddle about south-southeast of the top of Millstone Hill and about 200 feet below it. (See Pl. II, No. 14.) Operator, Wetmore & Morse Granite Co., Montpelier.

The granite (specimen D, XXIX, 19, b), "light Barre," is a biotite granite of light, medium, slightly bluish-gray color (darker than that of the Jones Light quarry and that of Hallowell, Maine, but lighter than "Concord granite") and of even-grained fine inclining to medium texture, with feldspar up to 0.3 inch and mica not over 0.1 inch. Its constituents, qualities, etc., are identical with those of specimen 18, a, from the Smith Upper quarry described beyond. The quarry yields also some "medium."

The stone effervesces with muriatic-acid test. W. T. Schaller, chemist, of this Survey, finds that it contains 0.49 per cent of CaO (lime) soluble in warm dilute (10 per cent) acetic acid, indicating a content of 0.87 per cent of $CaCO_3$ (calcium carbonate, calcite); the presence of this mineral is also shown in thin section.

The quarry, opened about 1875, measured in 1907 about 610 feet in a N. 60° E. direction by 100 to 200 feet across and in 1917 had reached a depth of 150 feet in some places and 100 feet in others.

Rock structure: The sheets are from 1 to 28 feet thick. The quarry cuts the axis of the hill so as to show the arching of the sheets on the north-northwest wall. They are horizontal in the center at the top and dip 10° E. and W., but in the center at the bottom they dip 15° SSW., showing the dome structure of the hill. There are four sets of joints—(a), strike N. 60° E., vertical and steep S. 22° E., forms part of the south-southeast wall; (b), strike N. 82° E., dip almost 90°, forms part of the north-northwest wall; (c), strike N. 35° W., vertical, occurring only in the north half of the quarry, coated with chlorite and sericite; (d), strike N. 30° E., dip 45° N. 60° W., greenish, slickensided. The rift is reported as vertical with northeasterly course, and the grain as horizontal. Rusty stain is up to 2 feet thick on upper sheets, but disappears entirely below.

The stone of this company's quarries has gone into the following monuments: That to Admiral Schley in Arlington Cemetery, Washington; that to Andrew J. Frame at Waukesha, Wis.; and the Everitt mausoleum at Bennington, Vt.

The **Smith Upper quarry,** southwest of and below the last, is S. 32° W. of the top of Millstone Hill, in Barre. (See Pl. II, No. 15.) Operators, E. L. Smith & Co., Barre.

The granite (specimen D, XIX, 18, a), "light Barre," is a biotite granite of light, medium, slightly bluish-gray color (darker than the "light" of the Jones quarry and that of Hallowell, Maine, which are light inclining to medium gray, but lighter than that of Corcord, N. H., which is medium gray) and of even-grained fine inclining to medium texture, with feldspar up to 0.3 inch and mica not over 0.1 inch. Its constituents, in descending order of abundance, are clear colorless to translucent bluish and milk-white potash feldspar (orthoclase, kaolinized and micacized, with a little fresh microcline); light smoky quartz with cavities in sheets with cracks parallel to or coinciding with them; translucent to milk-white soda-lime feldspar (oligoclase-albite more or less altered), rarely with flexed twinning planes; biotite (black mica), some of it chloritized and with epidote; a little muscovite or bleached biotite. Accessory: Pyrite, magnetite, titanite, apatite, zircon. Secondary: Calcite, generally in the orthoclase, kaolin, one or two white micas, chlorite, and epidote. It effervesces slightly with muriatic-acid test.

The mineral contrasts are feeble.

The quarry is very irregular in outline, measuring about 400 feet in a N. 30° E. direction by 200 feet across and about 50 feet in depth.

Rock structure: The sheets, 1 to 10, rarely 20 feet thick, are horizontal at the north end but elsewhere bend over to the southwest 10° to 15°. Joint and rift courses of this and Duffee and Smith Lower quarries are combined in figure 30. There are two sets of joints—(A), vertical, forming headings on the northwest and southeast walls; (B), dip 75° SW., spaced 10 to 30 feet and over. The rift is reported as vertical and grain as horizontal. Rusty stain 1 to 18 inches thick, but little of it on the upper surfaces of sheets.

The product is monumental stone. Specimens from all the quarries of E. L. Smith & Co. are: Tuxbury exedra at Saco, Maine (see Pl. IV); pedestal of equestrian statue of St. Louis (erected by W. R. Hodges) and Lemp mausoleum, St. Louis, Mo.; Cluett obelisk, with 44-foot shaft, Hegeman mausoleum, Woodlawn Cemetery, Troy, N. Y.; Fleischmann mausoleum, Cincinnati; Kaufman mausoleum, Marquette, Mich.

This company also furnished the stone for the Barre post office.

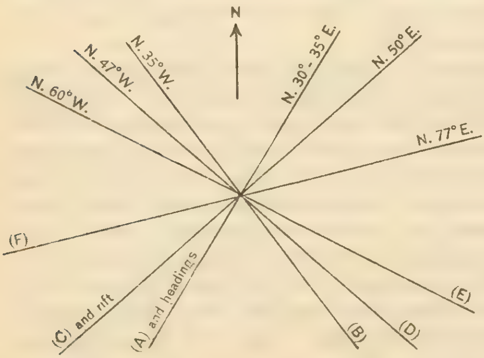

FIGURE 30.—Structure at Smith Upper, Smith Lower, and Duffee quarries, Barre, Vt.

The **Duffee quarry** is west-northwest of and lower than the Smith Upper quarry and southwest of the top of Millstone Hill, in Barre. (See Pl. II, No. 16.) Operators, E. L. Smith & Co., Barre.

The granite (specimen D, XXIX, 17, a), "medium Barre," is a biotite granite of medium bluish-gray color (a trifle darker than "Concord granite") and of even-grained fine texture with feldspars up to 0.2 inch and mica rarely to 0.1 inch. Its constituents, in descending order of abundance, are translucent bluish to milk-white potash feldspar (orthoclase, kaolinized and micacized, with a little fresh microcline); light smoky quartz with cavities in sheets and with cracks parallel to them, also showing optical effects of strain; translucent to milk-white soda-lime feldspar (oligoclase-albite, more or less altered), some of it with curving twining planes; biotite (black mica), some of it chloritized; a little muscovite or bleached biotite. There are microscopic veins of epidote, of quartz, and of calcite. Accessory: Allanite, zircon, probably also magnetite and pyrite, although not in section. Secondary: Calcite, usually in orthoclase, kaolin, one or two white micas, epidote, quartz, chlorite. The stone effervesces slightly with muriatic-acid test. The quarry produces some "dark" also.

The mineral contrasts are weaker than in the "dark" or in the "light" of the Jones or Smith Upper quarries, because of greater fineness of mica and more bluish cast of feldspar.

The quarry is estimated as about 400 feet east to west on one side and 300 on the other by 200 feet across and about 75 feet in depth.

Rock structure: The sheets, 2 to 12 feet thick, are somewhat regular, dipping 15° SW., with the rock surface. There are four sets of joints (see fig. 30)—(A), dip 75° S. 60° E., forms a 15-foot head through the center of the quarry and is spaced 10 to 100 feet; (B) dip 60° N. 55° E., one only in

southwest part; (C) dip 60° S. 40° E., one on south wall; (D) dip S. 43° W., one on southeast wall. The rift is reported as vertical and the grain as horizontal.

The **Smith Lower quarry** is west northwest of the Duffee quarry near the foot of Millstone Hill and S. 60° W. from its top, in Barre. (See Pl. II, No. 17.) Operators, E. L. Smith & Co., Barre.

The granite, "medium Barre," is identical with that of the adjoining Duffee quarry described above. The quarry also yields some "dark."

The quarry is estimated as about 250 feet east to west by 200 feet across, and 150 feet in depth.

Rock structure: The sheets, 1 to 15 feet thick, dip 20°-30° SW., but in the lower part is a mass 58 feet thick without sheets. Joint and rift courses are shown in figure 30—(A), dip 80° S. 60° E., forms the east wall and a heading on the southwest wall, and recurs 20 feet south of the north wall; (B), dip 50° NNW. (two of this set, 8 feet apart, are in the southeast corner); (C), dip 40° N. 55° E., one only, discontinuous, on northeast wall. Rift and grain as at adjacent quarries.

The **Millstone quarry** is N. 40° E. from the top of Millstone Hill and 200 feet below it, or 1,000 feet above the city, in Barre. (See Pl. II, No. 19.) Operators, E. L. Smith & Co., Barre.

The granite (specimen D, XXIX, 26, a), "coarse light Barre," is a biotite granite of light-gray shade, owing to more biotite a trifle darker than the "light" of Jones quarry, and of even-grained medium texture with feldspars up to 0.3 inch, exceptionally 0.4 inch, and mica to 0.2 inch. Its constituents, in descending order of abundance, are clear colorless to milk-white potash feldspar (orthoclase, kaolinized and micacized, with a little fresh microcline, rarely inclosed by the orthoclase); light smoky quartz with cavities in sheets, with rift cracks parallel to them, also showing optical effects of strain; whitish soda-lime feldspar (oligoclase to oligoclase-andesine) more or less altered; biotite (black mica), some of it chloritized; a little muscovite or bleached biotite. Accessory: Titanite. Secondary: Calcite, generally within the orthoclase, kaolin, one or two micas, chlorite. The stone effervesces with cold muriatic-acid test.

This is a light constructional granite.

In another opening a little north of the main one the stone (specimen D, XXIX, 26, b) "medium Barre," is a biotite granite of medium gray color and fine texture, with feldspars up to 0.2 inch, rarely 0.3 inch, and mica not over 0.1 inch. Its constituents are the same as in the coarser granite, except that the soda-lime feldspar is oligoclase and some of the orthoclase is fresh. The stone effervesces slightly with muriatic-acid test.

This is a monumental granite.

The main quarry, opened in 1902, measured in 1907 about 200 feet in a N. 35° E. direction by 150 feet N. 25° W., and in 1917 was about 50 feet deep.

Rock structure: The sheets are regular, 6 inches to 7 feet thick, and dip gently northeast. There are two sets of joints—(a), strike N. 25° W., vertical, forms the northeast wall and a heading 75 feet from the southwest wall; (b), strike N. 35° E., vertical and steep N. 55° W., one only, forming the north wall. Some of the joint faces are coated with muscovite scales. The rift is reported as vertical with N. 35°-40° E. course, and the grain as horizontal. For spaces 1 to 2 inches wide the granite has very little biotite, and the average size of feldspars is there greater. A basic dike, described on page 128, runs parallel to the north wall and a little back of it. It is 2 feet thick but tapers out at heading (a). Rusty stain does not exceed 1½ inches on sheet surfaces.

The **Barclay quarry** is the S. 35° W. continuation of the large Jones Light quarry, as shown on Plate II, No. 12. Operator, Standard Granite Co., Barre.

The granite, "light Barre," is a biotite granite of light, slightly bluish-gray color and even-grained fine inclining to medium texture, identical in every respect with that of the Jones light quarry described on page 133, but the lower part of the quarry is said to have yielded "medium Barre" granite.

The quarry in 1907, 220 by 100 feet, was about 75 feet deep.

Rock structure: The sheets, 6 inches to 12 feet and over in thickness, dip 20° N.W., but sheet structure terminates at a depth of 35 feet. Joints and rift are the same as in the Jones Light quarry. The granite is capped by schist on the northwest side. The schist is spangled with minute crystals of biotite and with a few garnets.

The product is used for monuments and memorial chapels. Specimens are the Robert Burns statue and pedestal, Barre, shown in Plate V, A; First North Dakota soldiers' memorial, St. Paul, Minn.; Indian massacre memorial, Serena, Ill.; Wade memorial chapel, Cleveland, Ohio; Hancock (canopy) memorial, San Francisco, Calif.; Doctor Kimball memorial, Concord, N. H.; General Thomas (shaft) memorial, Springfield, Ohio; Senator Dillon shaft, Davenport, Iowa.

The **Sunnyside quarry** is in line with the Barclay. It is operated by the Sunnyside Granite Co., Barre.

The **Wells-Lamson quarry** is 640 feet above the city and about northeast of the top of Millstone Hill. (See Pl. II, No. 24.) Operator, Wells-Lamson Quarry Co., Barre.

The granite, "light and medium Barre," is a biotite granite of light medium, slightly bluish-gray, or of medium bluish-gray color, and of even-grained fine inclining to medium or fine texture. It is reported as identical in quality with the "light" and "medium" of the Smith Upper and Duffee quarries described on pages 135, 136. The following result of a microscopic examination of "dark" granite from this quarry, made by Whitman Cross, of this Survey, was published in 1898: [69]

"Messrs. Wells, Lamson & Co.'s dark granite is a fine, even-grained, typical granite containing two micas (biotite, muscovite), sometimes called granite proper. The constituents of importance are quartz, orthoclase, microcline, biotite, and muscovite. The first three occur in wholly irregular grains interlocking in a very complex manner. The micas are in small leaves between and penetrating the other minerals to some extent. Muscovite apparently occurs in two forms, one corresponding to the biotite, as seemingly primary, and the other in small flakes in the orthoclase, and clearly a secondary mineral. Accessory constituents are oligoclase, albite(?), titanite (sphene), and apatite. There is an almost total absence of magnetite or other iron ore. Biotite is slightly changed to green and probably yields chlorite in some samples. The orthoclase gives way to an aggregate of fine muscovite leaves, also varying much in different samples, no doubt. Both quartz and biotite show that the rock has endured considerable pressure, the former by the 'undulatory extinction' it exhibits, and the biotite by the curved and bent lamellae. The pressure did not extend to a crushing of the grains or any banded structure. In the feldspars is some calcite filling small cracks. On the basis of this examination I should estimate it at quartz 30 to 35 per cent, orthoclase 30 per cent, microcline 20 to 25 per cent. Much of the iron is present in the ferrous or unoxidized condition."

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[69] See U. S. Geol. Survey Nineteenth Ann. Rept., pt. 6, continued, p. 224, 1898.

A chemical analysis of the "dark" from this quarry made by William C. Day at Swarthmore College, Pennsylvania, published in the same place, is repeated here for reference.

Analysis of "dark Barre" granite.

Silica (SiO_2)	69.56
Alumina (Al_2O_3)	15.38
Iron sesquioxide (Fe_2O_3)	2.65
Magnesia (MgO)	Trace.
Lime (CaO)	1.76
Soda (Na_2O)	5.38
Potash (K_2O)	4.31
Manganese (Mn)	Trace.
Loss on ignition, CO_2, and moisture	1.02
	100.06

Day also made the following physical determinations of "dark" and "medium" from this quarry:[70] Specific gravity, dark, 2.672; medium, 2.662; water absorbed, dark, 0.121 per cent; medium, 0.129 per cent; crushing strength, dark, 16,719 to 19,957 pounds; medium, 14,968 to 17,856 pounds.

The quarry, opened about 1885, was estimated in 1907 as measuring about 400 feet in a N. 25° W. direction by 300 feet across and from 50 to 60 feet in depth.

Rock structure: The sheets, 6 inches to 15 feet thick, dip gently southeast and N. 65° E. On the west side the lenses are very short. There is one sharply curving "toenail" 10 feet high, intersecting the sheet structure. There are three sets of joints—(a), strike N. 65°–70° E., dip 40°–60° N. 27° W., spaced 25, 50, and 200 feet; (b), strike N. 30° E., vertical, forms a small heading on south edge only; (c), strike N. 45° E., vertical, forms a heading on the north wall and is spaced 200 feet and over. The rift is reported as vertical (probably N. 30° E.), and the grain as horizontal. A 12-inch band of darker granite strikes N. 70° E. and dips 60° N. 20° W., marking the direction of the flow. Schist crops out close to the south wall and continues in that direction. A north-south compressive strain is reported.

The product is used for monuments and buildings.

The **Consolidated quarry** is 860 feet above the city and N. 75° E. from the top of Millstone Hill, in Barre. (See Pl. II, No. 26.) Operator, Wetmore & Morse Granite Co., Montpelier. Idle since 1920.

The granite, "light Barre," is a biotite granite of light medium, slightly bluish color like that of the Wetmore & Morse and Smith Upper quarries, and of even-grained fine inclining to medium texture. (See p. 135.)

The quarry was estimated in 1907 as measuring about 300 feet from north to south by as much across and in 1917 was from 75 to 100 feet deep.

Rock structure: The sheets, 1 to 15 feet thick, the thicker ones generally 5 to 10 feet, in places irregular, dip 15° E. There are four sets of joints, as shown in figure 31—(A), dip 35° N. 40° W., one on the west wall, and a heading at the southeast corner; (B), dip 75° W., one at the southeast corner; (C), dip 50°–80° N. 20° W., forms north and south walls and small heading 30 feet west of the south wall; (D), dip 75° N. 60° E., one crosses the quarry from the northeast corner. The rift is reported as vertical and the grain as horizontal.

[70] Idem, pp. 225, 226.

The **Empire Light Granite quarry** is about 800 feet east-southeast of the Milne quarry, on the north side of the southern road from Websterville to East Barre. (See Pl. II, No. 36.) Owners, E. L. Smith & Co., Barre.

The granite, "light and medium Barre," is a biotite granite of light medium and medium, slightly bluish-gray color, and of even-grained fine inclining to medium texture. (See p. 124.)

The quarry, opened about 1889, was estimated in 1907 as about 375 by 200 feet and from 10 to 50 feet deep. It was not operated in 1917.

Rock structure: The sheets are normal, 1 to 16 feet thick, dipping 10° SE. There are two sets of joints—(a), strike N. 70° E., dip 53° S. 20° E., spaced 10 to 50 feet and over; (b), strike northwest, dip 75° SW., discontinuous, spaced 100 feet and over. The rift is reported as vertical with N. 35° E. course, and the grain as horizontal.

The **Milne quarry** is on the south side of the southern road from Websterville to East Barre and 0.9 mile east-southeast of the top of Millstone Hill, in Barre. (See Pl. II, No. 34.) Operator, Boutwell, Milne & Varnum Co., Montpelier.

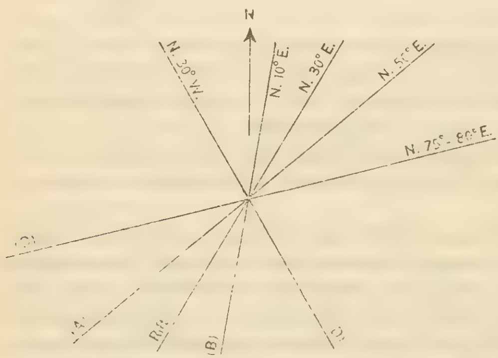

FIGURE 31.—Structure at Consolidated quarry, Barre, Vt.

The granite, "light and medium Barre," is a biotite granite of light medium and medium bluish-gray color, and of even-grained fine inclining to medium texture. (See pp. 135–136.)

The quarry was estimated in 1907 as measuring about 250 feet in a north-northwest direction by 250 feet across and from 55 to 70 feet in depth.

Rock structure: The sheets, 1 to 6 feet thick, are about horizontal or dip 20° E., but disappear 25 feet below the rock surface, where low-dipping joints are used by the quarrymen instead. There are four sets of joints, as shown in figure 32—(A), vertical, dip 20° and 40° N. 60° W., forms the east-southeast wall, spaced 3 to 150 feet, coated with coarse scales of muscovite; (B), dip 40° NW., discontinuous, spaced 15 to 150 feet; (C), dip 70° S. 15° E., spaced 2 to 20 feet and over, but stop 20 feet down; (D), dip 75° S., one only, at the south corner. The rift is reported as vertical with N. 35° E. course, and the grain as horizontal. There are veins of smoky quartz up to 2 inches thick, at intervals of about 3 feet, dipping 60°. Some with another strike are part pegmatite. The microscopic structure of this quartz has been described on page 51.

The **Straiton quarry** is about 1¼ miles east-southeast of the top of Millstone Hill, in Barre. (See Pl. II, No. 37.) Operator, George Straiton Quarry Co., Barre.

The granite, "light and medium Barre," is a biotite granite of light medium and medium gray shade and of even-grained fine inclining to medium texture like that previously described.

The quarry, opened in 1905, measured in 1907 about 100 feet square and averaged 10 feet in depth.

Rock structure: The sheets, 1 to 5 feet thick, vary from horizontal to a dip of 10° about south. There is but one set of joints; strike N. 65° E., dip 55° S. 25° E., spacing 1 to 20 feet. The stain is up to 6 inches thick.

The product is used for buildings and monuments.

The **Jones Dark quarry** is in Williamstown (Orange County) but adjoins the Empire quarry in Barre. (See Pl. II, No. 38.) Operator, Jones Bros. Co., Barre, Vt., and Boston, Mass.

The granite (specimen D, XXIX, 13, a), "dark Barre," is a biotite granite of dark bluish-gray color, a trifle darker than that of the Bruce quarry, and of even-grained fine inclining to medium texture, with feldspars up to 0.3 inch and mica to 0.1 inch. Its constituents are identical with those of the Milne & Wylie quarry stone described on page 129. It effervesces with muriatic acid test.

The polished face shows pyrite and a little magnetite. The polish is fair. Its cut hard-way face is as light as that of the "light Barre," and thus in marked contrast to its polished face. Its mineral contrasts and qualities are identical with those of the Milne & Wylie quarry stone (p. 129), but its texture, particularly its mica, appears to be a little finer.

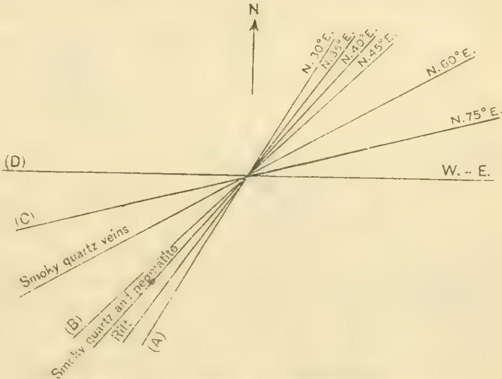

FIGURE 32.—Structure at Milne quarry, Barre, Vt.

The quarry, opened about 1886, was estimated in 1907 as measuring about 300 feet in a N. 80° E. direction by 250 feet across and in 1917 was 125 feet deep.

Rock structure: The sheets, 2 to 20 feet thick, are irregular and undulating. There is one mass 28 feet thick. There are four sets of joints—(a), strike N. 80° E., vertical, forms headings on north and south walls, is spaced 5 to 30 feet, and has rusty faces; (b), strike N. 15° W., vertical, usually discontinuous vertically, spaced 10, 20, 30, and 200 feet; (c), strike east, dip 55° S., discontinuous, one only in southern part; (d), strike N. 55°–55° E., dip 37° S. 37° E., forms a small heading north of the south wall. The rift is reported as vertical, with course of about N. 55° E., and the grain as horizontal. A schist inclusion in the west wall is 30 feet long with a foliation striking N. 50° E. There are also masses of darker granite of roundish outline up to 3 feet in diameter, like those in the Marr & Gordon quarry (p. 131). Rusty stain is up to 6 inches thick on sheet surfaces.

The **Pirie quarry** is in Williamstown (Orange County), nearly 1½ miles south-southwest of the top of Millstone Hill. (See Pl. II, No. 40.) Operator, James K. Pirie estate, Barre.

The granite, "dark Barre," is a biotite granite of dark, slightly bluish-gray color and of even-grained fine inclining to medium texture like that of the Barre quarries described on page 124.

The quarry, opened in 1882, was estimated in 1907 as measuring 350 feet in a northeasterly direction by 100 and 250 feet across, and from 30 to 100 feet in depth.

Rock structure: The sheets are normal, 1 to 12 feet thick, and dip 10°–30° NNW. Joint, rift, and dike courses are shown in figure 33. Joint set (A), dip 60° S. 27° E., forms part of the west wall and a rusty heading across the center of quarry; (B), dip 55° S. 55° E., forms the east wall, spaced 1 to 20 and over 50 feet, also very rusty; (C), dip 55° E., only three, spaced 10 feet; (D), about vertical, discontinuous, spaced 30 feet. The rift is reported as vertical, and the grain as dipping about 35° N. 30° W. A 3-foot 6-inch pegmatite dike dipping 65° S. 25° E. crosses the center of the quarry and sends out tapering branches up to a foot in length. (See, further, p. 49.) Stain up to a foot thick is mostly confined to the underside of sheets.

The **Wildbur quarry** is on the west side of Cobble Hill, 600 feet above the city and N. 35° E. from the top of Millstone Hill, in Barre. Operators, Wildbur Bros. & Bessey, Barre. Idle since 1909.

The granite (specimen D, XXIX, 31, a), "light Barre," is a biotite granite of light medium gray shade (like Jones "light Barre") and of even-grained fine inclining to medium texture, with feldspars up to 0.2 inch and mica to 0.1 inch. The mica is finer and more abundant than in the stone of Wheaton quarry. Its constituents are identical with those of Jones "light Barre" described on page 133. A clear microcline incloses an altered orthoclase. The quartz shows effects of strain and conspicuous rift cracks parallel to or coinciding with sheets of cavities. Some of these cracks polarize brightly and continue into the feldspars, where they are clearly filled with fibrous muscovite. The stone effervesces with muriatic-acid test.

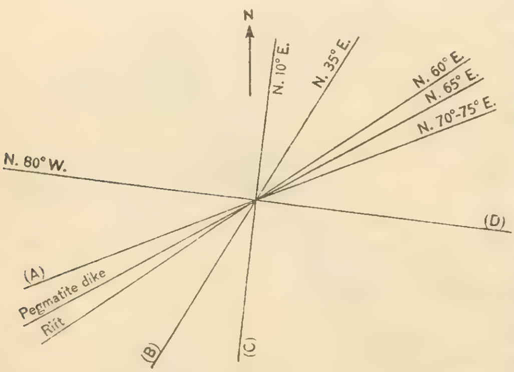

Figure 33.—Structure at Pirie quarry, Williamstown, near Barre, Vt.

The quarry was estimated in 1907 as measuring 100 feet east and west by 75 feet across. It had a working face 80 feet high on the east.

Rock structure: The sheets, 1 to 8 feet thick, becoming thicker eastward, appear to belong to the outside of an arch or dome striking here N. 10°–20° W. and dipping 60° S. 75° W. One set of joints only—strike N. 75° E., dip 70° S. 15° E., spaced 8 to 30 feet and over. The rift is reported as vertical with N. 75° E. course, and the grain as horizontal.

The product is used for monuments and buildings.

This quarry was idle in 1916.

The **Barre Medium quarry** is about 500 feet southeast of the Milne quarry. (See Pl. II, No. 35.) Operator, Barre Medium Granite Co., Barre. Idle in 1922.

The granite, "medium and light Barre," is a biotite granite of medium and light medium bluish-gray color and even-grained fine inclining to medium texture like that described on pages 135–136.

The quarry, opened in 1906, was estimated in 1907 as measuring 200 feet from north to south by 150 feet across and from 10 to 25 feet in depth.

Rock structure: Sheets 6 inches to 5 feet thick, increasing in thickness downward, dip low southeast. No joints had been found. The rift is reported as vertical with N. 60° E. course, and the grain as horizontal.

The **McDonald & Cutter quarry** is east-northeast of the top of Millstone Hill, east of the main street of Websterville, in Barre. (See Pl. II, No. 27). Operator, Wetmore & Morse Granite Co., Barre.

The granite is mostly "light Barre" with some "medium." It is a biotite granite of light medium or medium, slightly bluish-gray color and of even-grained fine inclining to medium texture, like those described on pages 135–136.

The quarry was estimated in 1907 as measuring about 200 feet in a N. 20° W. direction by 175 feet across and from 65 to 110 feet deep.

Rock structure: The sheets, in places imperfectly developed, from 3 to 30 feet thick, undulate horizontally. There are masses 40 feet thick without sheets. There are three sets of joints—(a), strike N. 10–15° W., vertical, forms the east and west walls, spaced 10 to 30 feet; (b), strike N. 40°–45° E., vertical, spaced 1 to 30 feet; (c) forms an irregular rusty heading at the northeast end, strike N. 15° E. and dip 70° E., but undulating along the strike. "Stain" is up to 14 inches thick.

The **Capital quarry** is 750 feet south-southeast of the McDonald & Cutter quarry and southeast of Millstone Hill, in Barre. (See Pl. II, No. 29.) Operator, Consolidated Quarry Co., Barre. Idle in 1921 and 1922.

For the granite, see under foregoing quarry.

The quarry was estimated in 1907 as measuring 150 feet in a northeast direction by 100 feet across and 50 feet in depth.

Rock structure: This is a "boulder" quarry. The sheets, 6 inches to 4 feet thick but extending to a depth of only 20 feet, dip about 10° SE. There are three sets of joints—(a), strike N. 65° E., dip 55° S. 25° E., spaced 3 to 10 feet, on south side only; (b), strike N. 35° E., dip steep N. 55° W., discontinuous; (c), strike northwest, dip 70° NE. spaced 5 to 20 feet. A basic vertical dike, 2 to 6 feet thick, with northeast course, forms the northwest wall. It weathers spheroidally. The rift is reported as varying in different blocks.

The **Canton quarry** is about 450 feet east-northeast of the Millstone quarry and northeast of the top of Millstone Hill, in Barre. (See Pl. II, No. 21.) Operators, E. L. Smith & Co., Barre.

The granite, "medium and light Barre," is a biotite of medium and light bluish-gray color, like those already described.

The quarry was estimated in 1907 as measuring about 300 feet in a northeasterly direction by 200 feet across and from 35 to 60 feet in depth.

Rock structure: The sheets, 1 to 14 feet thick, are normal and dip 10° N. There are two sets of joints—(a), strike N. 37° W., dip 80° N. 53° E., forms the east wall and a heading on the west wall, spaced 5 to 50 feet; (b), strike N. 35° E., dip 55° S. 55° E., spaced 10 to 25 and 200 feet, slickensided in the direction of dip. The rift is reported as vertical with N. 42° E. course, and the grain as horiontal. A marked east-west compressive strain is shown in the faulting of channel cores.

CABOT.

The town of Cabot adjoins Woodbury on the southeast and Walden on the northeast.

Lambert's prospect is in the northern corner of the township, on the east side of a north-south ridge, roughly about 4 miles east of Robeson Mountain in Woodbury and about 700 feet above Woodbury Pond. (See fig. 20.) It is on the farm of Myron Goodnough, near the Walden line, on the South Walden road which leads from Cabot to Hardins. Operator, Cabot Granite Co. (Joseph Lambert), Hardwick.

The granite (specimen D, XXIX, 59, a), "dark gray," is a quartz monzonite of dark bluish-gray color (as dark as "dark Barre") and of even-grained fine

texture with feldspars and mica up to 0.2 inch, the latter rarely 0.3 inch. Its constituents, in descending order of abundance, are clear quartz with fluidal and other cavities in sheets and with rift cracks parallel to them filled with fibrous muscovite and extending into the feldspars; bluish-gray to milk-white soda-lime feldspar (oligoclase, but little kaolinized, micacized, and with calcite); bluish-gray potash feldspar (orthoclase, kaolinized and micacized, with microcline); greenish biotite (black mica); and a little muscovite or bleached biotite. Accessory: Pyrite, titanite, apatite, and allanite (a crystal 0.33 by 0.09 millimeter rimmed with epidote). Secondary: Calcite, epidote, kaolin, and one or two white micas. Effervesces slightly with muriatic-acid test.

This stone is a little finer textured than some of the "dark Barre" and more micaceous. Its mineral contrasts are more marked owing to its feldspars being whiter and less bluish and its quartz not smoky. It ought to hammer light.

The quarry was opened in 1904. A little work was done in 1907 and more later, but operations were suspended in 1915.

The sheets in 1907 were not yet sufficiently exposed to show their thickness. There are five sets of joints—(a), strike N. 85° E., dip 75° N.; (b), strike N. 55° W., dip 55° S. 35° W.; (c), strike N. 65° E., dip 25° NNW.; (d), strike N. 5° E., vertical; (e), strike N. 60° E., dip 75° S. 30° E.

CALAIS.

The town of Calais adjoins Woodbury on the southwest. The quarries are at Adamant (formerly known as Sodom), in the west corner of the town and 6 miles north-northeast of Montpelier.[71] (See Pl. I.) The quarries lie along a N. 30° E. line on the southeast side of a granite ridge. The granite is a biotite granite of medium and light-gray shade and fine texture. Of geologic interest is the absence of sheet structure and the occurrence of graphite in connection with the quartz veins. Schist crops out below the quarries at the village, with a foliation striking N. 20° E. and dipping 55° W.

The **Patch quarry** is within half a mile of Adamant, in Calais. Operator, Hughes Granite & Quarry Co., Montpelier.

The granite (specimen D, XXIX, 52, a) "medium gray," is a biotite granite of medium, slightly bluish-gray color and of even-grained medium texture, with feldspars up to 0.3 inch, rarely 0.4 inch, and mica up to 0.1 inch. The larger feldspars are crystallized about the quartz and mica up to 0.1 inch. The larger feldspars are crystallized about the quartz and mica and give the stone a somewhat porphyritic texture. Its constituents, in descending order of abundance, are clear colorless potash feldspar (orthoclase, somewhat kaolinized and micacized, with microcline) with inclusions of the other constituents; clear, colorless quartz with but few cavities; bluish to milk-white soda-lime feldspar (oligoclase-albite more or less altered); biotite (black mica); and a little muscovite or bleached biotite. Accessory: Apatite and zircon. Secondary: Kaolin, calcite, and white mica. It effervesces slightly with muriatic acid test.

This granite is of the same shade as "medium Barre" but of less bluish and more greenish tinge. Its mineral contrasts are stronger and its texture a little coarser. Its large clear feldspars give brilliancy to its rough surface.

The quarry, opened about 1893, was estimated in 1907 as measuring 250 feet from north to south by 150 feet across and from 20 to 50 feet in depth.

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[71] See U. S. Geol. Survey Bull. 589, pl. 1 (map of Vermont with township lines), 1915; also Vermont State Geologist Tenth Rept., pl. 38 (geologic sketch map of Calais, by C. H. Richardson), 1916.

Rock structure: Sheet structure is absent. There are two sets of joints—(a), utilized as sheets in quarrying, strike N. 85° E., dip 50° S., spaced 2 to 17 feet and slickensided in a southwest direction; (b), strike like (a), dip 40° N. to 90°, spaced 20 to 75 feet, in places discontinuous. The rift is reported as striking N. 30° E. and dipping 50° N. 60° W., and the grain as striking and dipping as joints (a). The "sap" is 4 inches thick on joint faces. A small vein of smoky quartz parallel to joints (a) contains large limonite particles from the alteration of some iron mineral. The slickensided face of this vein is graphitic.

Transportation, by cart, 7 miles to Montpelier.

The product is used for monuments and finds a market chiefly in the Middle West.

The **Lake Shore quarry** is about 1,200 feet S. 32° W. from the Patch quarry, near Adamant, in Calais. It was abandoned before 1915.

The granite (specimen D, XXIX, 53, a) is a biotite granite of light inclining to medium gray shade and of even-grained fine texture, with feldspars up to 0.2 inch and mica to 0.1 inch, rarely 0.2 inch. The larger feldspars are crystallized about the quartz and mica, giving the stone a somewhat porphyritic texture. Its constituents are identical with those of the Patch quarry stone, except that it contains secondary epidote in particles up to 0.5 millimeter. It effervesces slightly with cold dilute muriatic acid.

This stone is a trifle darker than "light Barre" and a trifle lighter than "medium Barre." Its shade corresponds to that of the granite of Hallowell, Maine, but its contrasts are stronger. Its other qualities are identical with those of the Patch quarry stone.

The quarry in 1907 was about 300 feet long in a N. 60° W. direction by 250 feet across and from 20 to 40 feet deep.

Rock structure: Sheet structure is undeveloped. There are three sets of joints—(a), utilized as sheets in quarrying, strike N. 80° E., dip 80° S., spaced 1 to 18 feet; (b), strike N. 75° E., dip 30° N. 15° W., only two on south wall; (c), strike N. 20° E., dip 30° W., discontinuous, at intervals of 20 feet and over. The rift was reported as having a N. 20° E. course and dipping 70° N. 20° W.

WOODBURY.

TOPOGRAPHY.

The township of Woodbury lies northeast of Calais, northwest of Cabot, and southwest of Hardwick. Its principal quarries are on the southeast flank of Robeson Mountain, about a mile east of Woodbury Center and 3 miles north-northeast of Woodbury (Sabins) Pond. (See maps, Pl. I and fig. 20.) Robeson Mountain is a ridge about a mile long with an axis curving from N. 80° E. to S. 70° W. Its top is 300 to 400 feet above the hollows on either side and 930 feet above Woodbury Pond and about 1,100 feet above the railroad at Hardwick. Granite has also been quarried on the ridges on the northwest and southeast sides of Buck Pond and on the rising ground at the head of the hollow on the north side of Robeson Mountain. This mass is continuous with the ridge southeast of Buck Pond. Granite has also been quarried on the north and northeast foot of Nichols Ledge, a bold cliff about 3 miles N. 70° E. from Robeson Mountain and 740 feet above Woodbury Pond, in the east corner of the town east of Nichols Pond. The granite masses referred to are all within an area of about 3½ miles square, occupying the northeastern part of the town.

GENERAL GEOLOGY.

In the Vermont report of 1861 all the central and eastern part of the town appears as "calciferous mica schist." A belt of "clay slate" is represented as crossing the western part of the town in a north-northeastern direction.

In Richardson's sketch map of the geology of Woodbury[72] the granite mass in the northeastern part of the town is represented as bordered on three sides by Ordovician limestone, although the granite is in contact with schist at several points. This is explained on page 314 of his paper in these words: "On Robeson Mountain in Woodbury the original capping of the granite mass contained both calcareous and noncalcareous beds of sediments. The calcareous outcrops now predominate, and therefore no phyllites appear in this area on the areal map."

Schist crops out on the northwest side of Robeson Mountain with a bedding strike of N. 70° W. and vertical dip and north pitch; also on the west-southwest side with a N. 67° E. strike and a dip of 55° N. 23° W. This would indicate a synclinal structure for the schist of this mountain. Schist also crops out near the quarries on the rising land north of the mountain, and appears also to cap the ridge east of the north end of Buck Pond. This is a muscovite-quartz-biotite schist with interbedded calcareous quartzite. The contact of schist and granite on Robeson Mountain has been described on page 88. The mountain appears to be an oblong dome in structure with an east-northeast to west-southwest axis, the sheets of which, horizontal at the top, bend over to 15° to 20° on the northwest and southeast sides, although in places still covered by schist. Nichols Ledge is another conspicous eminence in the same granite mass. The granite of the top is coarsely porphyritic, with feldspars an inch long, but at its north and northeast foot there is a granite of fine texture, possibly a dike in the coarser. The foliation of a schist mass back of the Webber quarry, between Buck Pond and Robeson Mountain, strikes N. 20° E.

"WOODBURY GRANITES."

The "Woodbury granites" are all biotite granites either of more or less bluish-gray color, ranging from dark to light, or else of a cream-tinted light gray, and ranging in texture from very fine to medium. They fall into four kinds, but, taking account of minor differences, into nine varieties. Most of them possess in large masses one general characteristic: They carry sparse more or less incomplete crystals up to an inch across of clear potash feldspar formed about the other minerals. There is some parallelism between these crystals, for seen at a certain angle the cleavage planes of adjoining crystals reflect the light alike.

The granites of Robeson Mountain range from light to medium gray in shade and from medium to fine, inclining to medium, porphyritic in texture. Their constituents, in descending order of abundance, are clear to translucent bluish potash feldspar (orthoclase and microcline), rarely somewhat kaolinized, its large particles with inclusions of biotite, quartz, and soda-lime feldspar; light to medium smoky quartz with hairlike crystals of rutile and fluidal and other cavities in sheets in two rectangular sets parallel to rift and grain cracks, respectively (some of the rift cracks extend into the feldspars and are filled with fibrous muscovite); milk-white soda-lime feldspar (oligoclase to oligoclase-albite), more or less kaolinized, micacized, and with calcite and in places epidote; biotite (black mica), some of it chloritized; a little muscovite or

[72] Vermont State Geologist Ninth Rept., pl. 53, 1914.

bleached biotite. Accessory: Pyrite, titanite, zircon, apatite, rutile. Secondary: Kaolin, a white mica, epidote, zoisite, calcite, limonite. Some of the feldspars are minutely intergrown with quartz in vermicular structure.

Two estimates of mineral percentages by the Rosiwal method average as follows: Feldspar, 64.35; quartz, 29.15; mica, 6.48.

One chemical test (p. 148) shows it to contain 0.16 per cent of CaO (lime), soluble in warm dilute (10 per cent) acetic acid, indicating a content of 0.28 per cent of $CaCO_3$ (lime carbonate, calcite).

The general differences between the three varieties of granite on Robeson Mountain are these: In the stone from the Fletcher quarry the feldspar and quartz areas are rather large and well defined by differences of shade. In the stone from the Woodbury Lower quarry the quartz areas are finer, fewer, and less smoky. In the "Bashaw" the texture is finer and contrasts weaker than in either of the others.

The dark gray of the Drenan (65, a) and Webber (67, a) openings is of dark bluish-gray color and fine texture, with feldspars to 0.2 inch and mica to 0.1 inch. Its composition is identical with that of the granite of Robeson Mountain, but its quartz is clear and its feldspar is albite to oligoclase-albite. Its general shade is like that of "dark Barre," but its texture is finer.

The stone from the Nichols Ledge quarry is of light inclining to medium bluish-gray color and of very fine to fine texture, with feldspar to 0.15 and mica to 0.1 inch, with a few larger porphyritic clear feldspars. This is lighter and finer than the last. Its quartz is clear with apatite needles, and its second feldspar is oligoclase to oligoclase-andesine.

The stone of the Imperial Blue quarry (specimen 69, a, of 1907) is of medium to dark bluish-gray color and of fine to medium texture.

Finally, there is the very light, slightly cream-colored constructional granite of the Vermont White quarry, very near locality 65 (specimen 66, a, of 1907), which is of medium texture and speckled with black mica. Its quartz is smoky.

The minor differences in these granites appear in the descriptions of the stone of each quarry.

GEOLOGY OF WOODBURY QUARRIES.

The usual range in thickness of sheets is from 2 to 8 or 20 feet; the extremes are 1 to 40 feet. The double sheet structure at the Fletcher quarry has already been described on page 36 and is shown in Plate VI, *B*. The secondary, nearly horizontal set is from 5 to 9 feet thick. It recurs in the lower part of the main quarry of the Woodbury Granite Co. There is a northeast to southwest compressive strain at the Fletcher quarry near the axis of the mountain, parting and extending the upper sheets.

The joints divide themselves into six sets—(a), strike north to N. 10° E., with its complementary set (b), N. 85°–90° E.; (c), strike N. 20°–30° E., with its complementary set (d), N. 50°–65° W.; (e), strike N. 20°–30° W., with its complementary set (f), N. 60°–65° E. The spacing of these joints ranges from 2 to 200 feet but is mostly from 10 to 40 feet. Headings, 3 to 30 feet wide, of set (a) are spaced 30 to 50 feet on Robeson Mountain. The rift is reported as vertical with courses of N. 15°, 26°, 35°, and 60° E., and the grain as uniformly horizontal. At one quarry the rift has to be followed closely in winter, but the rock is reported as splitting with equal facility in any direction in summer.

Flow structure appears with a dip of 50° SW. There is an irregular banding at one of the Drenan openings caused by unequal distribution of biotite.

The schist capping is exposed at another of the Drenan openings, and the 100-foot mass of schist at the back of the Webber quarry is either part of the same or a very large inclusion. The schist inclusions on Robeson Mountain, 25 and 8 feet long, are referred to on page 150. A small light-greenish calcareous inclusion at the Ainsworth quarry proves to be chiefly crystalline calcite with quartz particles under 0.1 millimeter, together with apatite and secondary epidote and zoisite, and has veinlets of epidote, quartz, and calcite. This appears to have originally been a quartzose marble, and its interest lies in its evidence of the presence of calcareous rocks here prior to the granite intrusion.

There are biotitic segregations up to 2 feet in diameter. Small pegmatite dikes at the Chase quarries, near Buck Pond, strike about north, and a 4-inch quartz vein on the northwest side of Robeson Mountain strikes N. 35°–40° E.

QUARRIES.

The **Fletcher quarry** is on Robeson Mountain near its west-southwest end and on its southeast side, in Woodbury. (See fig. 20.) Operator, E. R. Fletcher, Woodbury.

The granite (specimens D, XXIX, 56, a, c), "Woodbury gray," is a biotite granite of light-gray shade (between "light Barre" and the granite of Hallowell, Maine, and of medium texture, with feldspars up to 0.3 inch and mica to 0.1 inch. Its constituents, in descending order of abundance, are clear to translucent bluish potash feldspar (orthoclase, some of it minutely intergrown with plagioclase, also microcline), the larger particles with inclusions of biotite and soda-lime feldspar; medium smoky quartz with hairlike crystals of rutile and cavities in two sets of rectangular sheets, with rift and grain cracks parallel to them; milk-white soda-lime feldspar (oligoclase-albite) much kaolinized, somewhat micacized and epidotized, and with calcite; biotite (black mica) some of it chloritized; and a little muscovite or bleached biotite. Accessory: Pyrite, titanite, zircon, apatite, rutile. Secondary: Kaolin, a white mica, epidote, zoisite, calcite, limonite.

An estimate of the mineral percentages by the Rosiwal method yields these results with a mesh of 0.5 inch and a total linear length of 46.5 inches: Feldspar, 63.11; quartz, 31.22; mica, 5.67. The average diameters of the particles by the same calculation are, feldspars (adding 20 per cent to number for plagioclase), 0.103 inch; quartz, 0.1 inch; mica, 0.029 inch.

The stone effervesces very slightly with muriatic-acid test. W. T. Schaller, chemist of this Survey, finds that it contains 0.16 per cent of CaO (lime) soluble in warm dilute (10 per cent) acetic acid, which indicates a content of 0.28 per cent of $CaCO_3$ (calcium carbonate, calcite); the presence of this mineral is also shown by the microscope.

This is a brilliant granite with marked mineral contrasts. The quartz and feldspar areas are rather large and well defined. The polish is poor owing to the large size of the micas. The polished face shows some pyrite.

The quarry, opened about 1887, was estimated in 1907 as measuring 300 feet in a northwesterly direction, or across the ridge, by 300 feet along it, and from 20 to 40 feet in depth. It was really the beginning of a cross section of the ridge and dome and this fact has greatly facilitated quarrying operations.

Rock structure: The complex sheet structure here has already been described (p. 36) and is shown in Plate VI, *B*. The primary sheets, 1 to 5 feet thick, are horizontal at the northwest (upper) side of the quarry, but gradually bend over and dip 20°–30° SE. at the southeast (lower) side. The

secondary set, 5 to 9 feet thick, dips 5°–10° about west, across the other. There are three sets of joints—(a), strike N. 30° E., vertical, spaced 6 to 30 feet and over; (b), strike N. 65° E., dip 75° N. 25° W., one only, in southeast part; (c), strike N. 20° W., vertical, spaced 2 to 15 feet. There are no headings. Some of the joint faces are greenish, probably from chlorite. The rift is reported as vertical with N. 35° E. course, and the grain as horizontal. Flow structure consists of biotitic streaks of irregular course. Biotitic knots from 1 to 3 inches across are reported. There is a marked northeast-southwest compressive strain in the upper part of the quarry, raising the sheets and even forming new sheet partings. There is no rusty stain whatever on sheet surfaces.

Transportation, by siding from the Hardwick & Woodbury Railroad, which brings the stone 8 miles to the St. Johnsbury & Lake Champlain Railroad. (See fig. 20.)

The product is used for monuments and buildings. Specimens: Base of the General Sherman monument, Washington, D. C.; Crandall monument, Crandall Park, Glens Falls, N. Y.; Fort Meigs monument, Toledo, Ohio (100 feet high); Englewood National Bank, Chicago; Lincoln Savings Bank, Louisville, Ky.; Plymouth Building, Minneapolis, Minn.; Courthouse, Omaha, Nebr.; Old National Bank, Spokane, Wash.

The four **Robeson Mountain quarries** of the Woodbury Granite Co. are roughly from 1,400 to 2,100 feet N. 80° E. from the Fletcher quarry, in Woodbury. (See fig. 20.) Operator, Woodbury Granite Co., Hardwick.

The granite is of two sorts. Specimen D, XXIX, 57, b, and c, "Woodbury gray," is a biotite granite of medium-gray shade and medium texture, with feldspar up to 0.3 inch and mica to 0.1 inch. Its constituents, in descending order of abundance, are clear colorless to translucent bluish potash feldspar (microcline and orthoclase), somewhat kaolinized; light smoky quartz with hairlike crystals of rutile, and cavities in sheets with rift and grain cracks parallel to or coinciding with them; milk-white soda-lime feldspar (oligoclase), considerably kaolinized but not micacized or epidotized, in places intergrown with quartz in vermicular structure; biotite (black mica); and a little muscovite or bleached biotite. Accessory: Pyrite, apatite, zircon, rutile. Secondary: Kaolin and zoisite. Carbonate and epidote were not detected. There is no effervescence with muriatic-acid test.

An estimate of the mineral percentages by the Rosiwal method with a mesh of 0.3 inch and a total linear length of 38.1 inches yielded these results: Feldspar, 65.6; quartz, 27.1; mica, 7.3. The average diameters of all the particles by the same calculation is 0.084 inch; that of the feldspar (adding 20 per cent to the number for the plagioclase as in calculation for average diameter), is 0.105 inch; quartz, 0.074 inch; and mica, 0.025 inch.

This stone to the eye is like that of the Fletcher quarry, except that its quartz particles are a little finer, less numerous, and less smoky. Its mineral contrasts are therefore weaker. The polish is poor, owing to abundant and rather large mica scales, but the contrasts on the polished face are strong. It shows a little pyrite.

The second sort (specimens D, XXIX, 57, a and d), "Woodbury Bashaw," is a biotite granite of medium-gray shade (about like that of "Concord granite" but more bluish and with more contrasts), and of fine inclining to medium texture with feldspars up to 0.2 inch and mica to 0.1 inch. Its constituents, in descending order of abundance, are clear to translucent bluish potash feldspar (microcline and orthoclase), light smoky quartz with cavities in two sets of rectangular sheets, with rift and grain cracks parallel to them, respectively, the rift cracks extending into the feldspars and filled with fibrous

muscovite; milk-white soda-lime feldspar (oligoclase), much micacized, with epidote and calcite, also intergrown with quartz in vermicular structure; biotite (black mica), some of it chloritized; a little muscovite or bleached biotite. Accessory: Pyrite, zircon crystals, apatite. Secondary: A white mica, epidote, calcite, chlorite. The stone effervesces slightly with muriatic-acid test.

This is a monumental granite. Its mineral contrasts are not as marked either in the rough or the polish as in the "Woodbury gray." This is due to the feldspars being less kaolinized and thus less white. Its texture is finer and it polishes better. The polished face shows a little pyrite.

Three compression tests of the "Woodbury gray" made for the firm at the United States Arsenal at Watertown, Mass. (test No. 13261), yielded these results: First crack, 199,000, 181,000, 168,000 pounds; ultimate strength, 22,460, 19,850, 20,110 pounds; average, 20,806 pounds per square inch.

The quarries consist of four openings. Their dimensions were estimated in 1907. The main and western one, made in 1880, beginning at the south foot of the ridge, extends about 500 feet along it and 400 feet northward up its side, with an average depth of 50 feet. The "upper quarry," above and north of the main one, is about 200 feet square, and its north side is at the top of the hill nearly 300 feet higher than the lower edge of the main quarry. The third opening, about 800 feet east of the main one, made in 1906, is about 125 by 70 feet and from 10 to 30 feet deep. This produces the finer monumental granite, "Woodbury Bashaw," described on page 149. The fourth is a small opening made in 1907, about 200 feet northwest of the third.

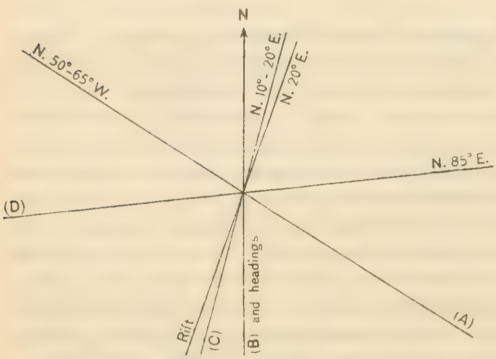

FIGURE 34.—Structure at Woodbury Granite Co.'s quarries, on Robeson Mountain, Woodbury, Vt.

Rock structure: The sheets at the top of the upper quarry and of the ridge are horizontal. In the third opening they are from 2 to 13 feet thick, ill defined, and about horizontal. In the main quarry they range from 2 to 18 feet, exceptionally 23 feet and even 40 feet, curving over from the horizontal to dip 20° S. They are intersected by a horizontal set. (See pp. 36, 148.) The joint courses (shown in fig. 34) are four—(A), dip 60°-65° N. 35° E. (some vertical, discontinuous), spaced 20 to 40 and 200 feet; (B), vertical or dip 75° W., discontinuous along the dip, in third opening spaced 10 to 30 feet, but in main quarry mostly headings, five in all, 3 to 30 feet wide and 30 to 50 feet apart; (C), vertical, discontinuous, and much more open than (A) or (B); (D) is spaced 2 and 10 to 40 feet. The rift is reported as vertical, and the grain as horizontal but not marked. The rift has to be followed closely in winter, but in summer the rock splits almost any way. There are two schist inclusions in the main quarry, 25 by 10 feet and 8 feet by (?), also some smaller ones. Rusty stain is 1 to 18 inches thick on sheet surfaces.

The product is used both for buildings and monuments. Specimen buildings: Pennsylvania capitol, Harrisburg; Cook County courthouse, Chicago; base course and 36 interior polished columns of Kentucky capitol, Frankfort; City hall, Cleveland, Ohio; Hotel Pontchartrain, Detroit, Mich.; Mercantile Trust

Co. Building, St. Louis, Mo.; main entrance, State capitol, Boise, Idaho; Mandell residence, Boston; post office, New Bedford, Mass. Specimen monuments: Navy memorial (obelisk), national military park, Vicksburg, Miss.; soldiers and sailors' monument, Bloomington, Ill.; memorial archway, Port Huron, Mich.; clock on the Green, Waterbury, Conn.

The adaptability of this granite for carving is shown in Plate V, B, representing a panel on the Cook County courthouse.

The **Imperial Blue quarry** is on the southeast side of Buck Pond, in Woodbury Township. (See map, fig. 20, p. 109, quarry 69.) Operator, Woodbury Granite Co., Hardwick.

The granite (specimen D, XXXVIII, 21, a, b), "Imperial blue," is a biotite granite of medium to dark bluish-gray color and of fine to medium texture, with feldspars up to 0.2 inch (a few porphyritic ones to 0.4 inch) and mica to 0.1 inch.

Its constituent minerals, in descending order of abundance, are clear colorless potash feldspar (microcline), with inclusions of plagioclase and biotite; slightly bluish quartz; slightly milky soda-lime feldspar (oligoclase-andesine), somewhat kaolinized, with oriented inclusions of muscovite; biotite; muscovite. Secondary: Kaolin, carbonate. Slight effervescence with muriatic-acid test.

This is a monumental granite of bluish-gray tint. It takes a fair polish.

The quarry, reopened since 1907, has a working face about 100 by 150 feet.

Rock structure: The sheets, 5 to 8 feet thick, dip low to the south. One set of joints strikes about east; another about north.

The stone is used entirely for monuments and thus far for tombstones and small memorials.

The **Vermont White quarry** lies about midway between Robeson Mountain and Buck Pond (see map, fig. 20, locality 65), in Woodbury Township. Operator, Woodbury Granite Co., Hardwick.

The granite (specimen D, XXXVIII, 22, a, b), "Vermont white," is a biotite granite of general very light cream color and of medium-coarse texture, with feldspars up to 0.3, exceptionally 0.5 inch and sparse black mica to 0.15 inch. Its quartz is pale smoky and feldspars clear to milk-white and light cream color. The mica on near view is in strong contrast to the other minerals. The granite is a brilliant rock in the rough; its polished face is noticeably darker.

Its constituents, in descending order of abundance, are clear colorless potash feldspar (microcline and orthoclase), pale smoky quartz with cavities in sheets; milk-white to cream-colored lime-soda feldspar (oligoclase), generally kaolinized, some of it altered to a white mica, some with oriented inclusions of muscovite; biotite; muscovite. Secondary: Kaolin, carbonate, a white mica. Some effervescence with muriatic-acid test.

Rock structure: The quarry face is about 500 by 200 feet. Richardson[73] mentions inclusions of limestone and schist up to 30 by 15 feet, also a dike of amygdaloidal basalt with a zone of closely cleft granite beside it, the structure having probably resulted from the intrusion. (See further p. 58.)

The product is used chiefly for buildings. Specimens: Northwestern Mutual Life Insurance Building,[74] Milwaukee, Wis.; Museum of Fine Arts, Minneapolis, Minn.; soldiers and sailors' memorial, Wichita, Kans.; Bridgeport Trust Building, Bridgeport, Conn.

The **Ainsworth quarry** is on the northeast foot of Robeson Mountain, in Woodbury, about 1,000 feet northeast of the railroad. (See fig. 20.) Operator, Andrew A. Ainsworth, Hardwick. Quarry abandoned.

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[73] Vermont State Geologist Ninth Rept., pp. 323, 324, pl. 67, A, 1914.
[74] This edifice has 10 Corinthian columns of this granite, five stories high.

The granite is a biotite granite similar to that of the main quarry of the Woodbury Granite Co. (p. 149).

Rock structure: The sheets are from 15 to 20 feet thick. There are very dark gray knots up to 2 feet by 1 foot, with half-inch porphyritic feldspars, much fine biotite, and not a little pyrite. A small inclusion of fine-grained quartzose marble was noticed on page 148.

The **Drenan quarries** are in Woodbury, on the rising land north of the east end of Robeson Mountain, about 150 feet above the north spur of the Hardwick & Woodbury Railroad. (See fig. 20.) They are not in operation.

The granite (specimen D, XXIX, 65, a, 1907), is a biotite granite of dark bluish-gray color and fine texture, with feldspar up to 0.2 inch and mica to 0.1 inch, but with some large clear sparse porphyritic feldspars formed about the other minerals. As many of these have their cleavage parallel, the rough rock face seen at a certain angle has a brilliant sheen. Its constituents, in descending order of abundance, are clear colorless to translucent bluish potash feldspar (microcline and orthoclase), slightly kaolinized, with inclusions of biotite, quartz, and soda-lime feldspar; clear colorless quartz with cavities in sheets; bluish milk-white soda-lime feldspar (albite to oligoclase-albite), kaolinized and micacized, also with calcite; biotite (black mica); and a little muscovite or bleached biotite. Accessory: Pyrite, apatite, zircon. Secondary: Kaolin, a white mica, calcite, zoisite. Effervesces with muriatic-acid test.

This is a monumental granite of the same color as "dark Barre" but of finer texture. It is darker than any of the granites of Robeson Mountain.

The **Webber quarries** are in Woodbury, still farther north of Robeson Mountain, on a mass continuous with that on the southeast side of Buck Pond. (See fig. 20.) They are not in operation.

The granite of the main opening (specimen D, XXIX, 68, a, 1907) is a biotite granite of light bluish-gray color and of medium inclining to fine texture, with feldspars up to 0.3 inch and mica to 0.15 inch. It is slightly more bluish and finer textured than the gray of the main quarry of the Woodbury Granite Co. and lighter in shade than their "Bashaw" and a trifle darker than "light Barre." Its constituents, in descending order of abundance, are clear to translucent bluish potash feldspar (microcline and orthoclase), slightly kaolinized, with inclusions of biotite, quartz, and soda-lime feldspar; light smoky quartz with hairlike crystals of rutile and cavities in sheets; milk-white soda-lima feldspar (oligoclase-albite), kaolinized and micacized and with calcite, with rims radially intergrown with quartz; biotite (black mica), some of it chloritized; a little muscovite or bleached biotite. Accessory, magnetite, rutile. Secondary, kaolin, a white mica, calcite, chlorite, epidote. Scarcely any effervescence with muriatic-acid test.

The stone of an opening made in 1907 (specimen D, XXIX, 67, a) is a biotite granite of dark bluish-gray color and of fine texture, with feldspar up to 0.2 inch and mica to 0.1 inch, and with sparse clear porphyritic feldspars up to 0.3 inch, with inclusions of quartz and mica. This granite, as to its constituents, is identical with that of the Drenan quarry (specimen 65, a) described above, and it has the same peculiar sheen. Its soda-lime feldspar is oligoclase-albite. It effervesces with muriatic-acid test.

The **Nichols Ledge Carter quarry,** no longer operated, is at the northwest foot of Nichols Ledge in the east corner of the town of Woodbury. (See fig. 20.)

The granite (specimen D, XIX, 61, b) is a biotite granite of light inclining to medium bluish-gray color and of fine to very fine texture, with feldspars up to 0.2 inch and mica to 0.1 inch, also with larger porphyritic clear feldspars formed about the other minerals. It is finer textured than the stone of the new

Drenan and Webber openings (p. 152) and of lighter shade. Its constituents, in descending order of abundance, are clear colorless potash feldspar (orthoclase and microcline); clear quartz with apatite needles and some cavities in sheets; bluish to milk-white soda-lime feldspar (oligoclase to oligoclase-andesine), but little kaolinized; olive-colored biotite (black mica); and a little muscovite or bleached biotite. Some of the feldspar is minutely intergrown with quartz. Accessory: Titanite, apatite. Secondary: Kaolin, epidote, calcite. No effervescence with muriatic-acid test.

The sheets are up to 2 feet thick. There are some biotite knots.

WINDHAM COUNTY.

DUMMERSTON.

The Dummerston granite area lies 5½ miles north-northwest of Brattleboro and is shown on the State geologic map of 1861 as surrounded by "calciferous mica schist," with a belt of "clay slate" east of it along the Connecticut. The quarries and prospects are in the southern part of the town, on the sides of Black Mountain, and also half a mile south-southwest of it. (See Pl. I.) Black Mountain, as shown on the United States Geological Survey's topographic map of the Brattleboro quadrangle, is on the east side of West River, 4 miles west of Connecticut River. This is a roundish granite mass, probably of dome structure, a square mile in area, 919 feet above West River and 1,269 feet above sea level. The sheets on its southwest side dip 30° to 40° about west, and in its northwestern part, about 350 feet above the river, 30° N. 30° W., A mass of sheets, about 35 feet thick at the foot of the mountain, does not appear to be normally related either in the thickness of its sheets or in their attitude to the sheets above it. These thin sheets may be of more recent origin than the others or may be separated from them by a fault. The effect of compressive strain upon sheets in part of this quarry has been referred to on page 30 and illustrated in Plate VI, *A*.

The granites of Dummerston are quartz monzonites of very light gray and light bluish-gray shade and of even-grained medium or medium inclining to fine texture.

The **Black Mountain quarry** is at the southwest foot of Black Mountain, three-quarters of a mile south-southeast of the village of West Dummerston, in Dummerston, and 5 miles north-northwest of Brattleboro. Operator, Presbrey-Leland Quarries (Inc.), 681 Fifth Avenue, New York.

The granite, of two sorts, chiefly "Dummerston white" (specimen D. XXIX, 90, b), is a quartz monzonite of very light gray shade, speckled with bronze-colored mica (muscovite and biotite), and of even-grained medium texture, with feldspars up to 0.3 inch and mica to 0.1 inch. Its constituents, in descending order of abundance, are clear to pale smoky quartz, showing effect of strain, with hairlike crystals of rutile and a few fluidal cavities in sheets; milk-white soda-lime feldspar (oligoclase to oligoclase-albite), some of it with flexed twinning planes, kaolinized and micacized; clear potash feldspar (microcline and othoclase); muscovite and less biotite, apparently intergrown and bent or twisted with fibrous muscovite stringers extending out from them into and between the other particles. Accessory: Apatite, rutile. Secondary: Kaolin, white micas, epidote, zoisite, calcite. There are crush borders about the quartz and feldspar particles.

This stone effervesces slightly with muriatic-acid test. W. T. Schaller, chemist, of this Survey, finds that it contains 0.07 of CaO (lime) soluble in warm dilute (10 per cent) acetic acid, which indicates a content of 0.125

per cent of $CaCO_3$ (calcium carbonate, calcite); the presence of this mineral is also shown by the microscope.

A compression test, made on a 4-inch cube at the United States Arsenal at Watertown, Mass., in 1905, showed the first crack at 308,000 pounds, and an ultimate compressive strength of 27,810 pounds to the square inch.

This is a building granite of medium grain and very light shade, between that of North Jay, Maine, and that of Bethel, Vt., in whiteness.

The other granite (specimen D, XXIX, 90, a), "dark blue," is a quartz monzonite of light inclining to medium bluish-gray color and of even-grained fine inclining to medium texture, with feldspars up to 0.2 inch and mica to 0.1 inch. Its constituents are identical with those of the "white" (specimen 90, b), but its oligoclase-albite is bluish and less altered, and its mica is nearly all muscovite. It shows less calcite in thin section and does not effervesce with muriatic-acid test.

This is a monumental granite of light bluish-gray tint and without mineral contrasts.

The quarry, opened about 1877, was estimated in 1907 as measuring about 1,200 feet in a N. 20° W. direction along the base of the mountain, by 200 feet across and from 15 to 50 feet deep. It was reopened in 1921.

Rock structure: The sheets for a thickness of 25 to 35 feet above the road level and for a length of 100 feet are 6 inches to 2 feet thick and horizontal or slightly inclined west. Below the road level they measure up to 14 feet in thickness and dip 20° W., although horizontal for short spaces. Above this thin-sheeted mass they dip 30°–40° W. and are considerably thicker. At the north end of the quarry compressive strain forms new thin sheets and parts them. (See p. 30.) There are two sets of joints—(a), strike N. 15° E., vertical, spaced 7 to 30 feet; (b), strike N. 20° W., dip 80° N. 70° E., only one, at the south end. Flow structure strikes N. 22° E. and dips 80° N. 68° W. The rift is reported as vertical with N. 15° E. course and the grain as horizontal. Both are good. The gneissic structure is parallel to the "hard way." Pegmatite dikes from 0.25 to 3 inches thick, with large light bluish-gray unstriated feldspars, strike N. 10° E. The light-bluish granite occupies 350 feet of the north end of the quarry, the rest of it being "white." Knots are rare and up to 6 inches across. Rusty stain, up to 3 inches wide on the upper sheets, is generally absent from the lower ones.

The product is used for buildings, monuments and street work. Specimens: Post office at Troy, N. Y.; Diamond Bank, Pittsburgh, Pa.; McFadden Building, Chicago, Ill.; Royal Baking Powder Building and Plaza Hotel, New York City.

The **Clark quarries** are east of West Dummerston village, on the northwest side of Black Mountain. Operators, James Clark & Son, West Dummerston. Idle in 1921 and 1922.

The granite (specimen D, XXIX, 91, a) from the lower quary is a quartz monzonite of very light gray shade, with conspicuous black mica, and of even-grained medium inclining to fine texture, with feldspars up to 0.25 and 0.3 inch and mica to 0.15 inch. Its constituents, in descending order of abundance, are light smoky quartz showing effect of strain, and with some cavities in sheets; milk-white soda-lime feldspar (oligoclase-albite), kaolinized, micacized, and with calcite, also intergrown with quartz in vermicular structure; clear colorless potash feldspar (microcline and othoclase), with inclusions of the other feldspar and mica; biotite (black mica); muscovite or bleached biotite.

This differs from the "white" of the Black Mountain quarry in that the biotite is more prominent and the fibrous muscovite is absent.

The stone from the upper quarry appears to be exactly like the "white" of the Black Mountain quarry (p. 153).

The lower opening is about 150 feet above the river bank, and the upper about 330 feet. Both are small.

Rock structure: The sheets of the upper opening are from 6 inches to 2 feet 6 inches thick; those of the lower 10 to 12 feet. They strike N. 60° E. and dip 30° N. 30° W.

The **Bailey prospects** are on the west side of West River about a mile south-southwest of the Black Mountain quarry, in Dummerston. Owner, David J. Bailey, R. D., Brattleboro. Idle in 1921.

The granite from an opening about 200 feet above the road to Brattleboro is a quartz monzonite of light-gray shade and medium inclining to fine even-grained texture, with feldspars up to 0.25 inch and mica mostly under 0.05 inch and more thickly disseminated than in the "white" of the Black Mountain quarry. Its constituents are the same as in that stone, but the quartz is more smoky, the mica mostly biotite. The fibrous muscovite and crush borders are lacking.

This stone is of slightly finer texture and, owing to the smokiness of its quartz and the distribution and amount of its biotite, of slightly darker shade than the "white." It is lighter than "light Barre."

The opening represented by this specimen measured in 1907 200 by 15 feet, with a working face of 10 feet.

Rock structure: The sheets, up to 8 feet thick, dip 20°–25° N. 35° W. A granite ledge a little north-northwest of this quarry is crossed by a dike of fine granite, 30 feet wide, with a N. 10° W. course and dip of 50° W. It is of medium bluish-gray color and of very fine even-grained texture, with feldspar and mica up to 0.05 inch. In thin section its particles range from 0.074 to 1.1 millimeters in diameter. It is a quartz monzonite of similar composition to that of West Dummerston. Its mica is chiefly biotite. Feldspar and quartz are intergrown and have crush borders. The soda-lime feldspar is bluish gray and scarcely altered.

This fine granite, although probably harder than ordinary granites, may be found of economic value.

WINDSOR COUNTY.

BETHEL.

TOPOGRAPHY AND GENERAL GEOLOGY.

The State map of 1861 represented a small granite area in the east corner of the town of Bethel, surrounded by "calciferous mica schist," with a north-south belt of "clay slate" a little west of it. This granite is on Christian Hill, an elongated mass rising about 350 feet above the adjacent hollows, about 2 miles north of Bethel village and east of White River. Its general position is shown on the map (fig. 35).

The granite exposure is reported as at least half a mile long from north to south. Its width at the quarries is about 550 feet, with a border of finer less whitish granite on either side about 40 feet wide. The entire width between the schist on the east and west is not far from 625 feet, but there is said to be another narrower belt of granite several hundred feet east of the main one protruding through the schist. The mica schist immediately west of the granite strikes N. 10° W. and dips 57° E.; that east of the granite (a garnetiferous mica slate), with 12-inch calcareous beds, strikes north to N. 5° E. and is vertical. The mica schist, in places chloritic, north of and near Bethel, strikes N. 10°–15° W. and is vertical. While the main granite mass, from its lateral zones of finer granite, would appear to be a truncated arch or dome, its sheet structure all dips east, from 15° to 45° on the east and 30° on the west. The

vertical north-south flow structure with its alined discoid nodules of muscovite has been described on page 60, and the details of the contact of granite and schist are given on page 84 and shown in figures 8 and 9.

"BETHEL GRANITE."

The following description is based on specimens, rough and polished, and thin sections from both the Woodbury and Ellis quarries, which are but a few feet apart in one mass of contemporaneous origin and of identical composition and texture.

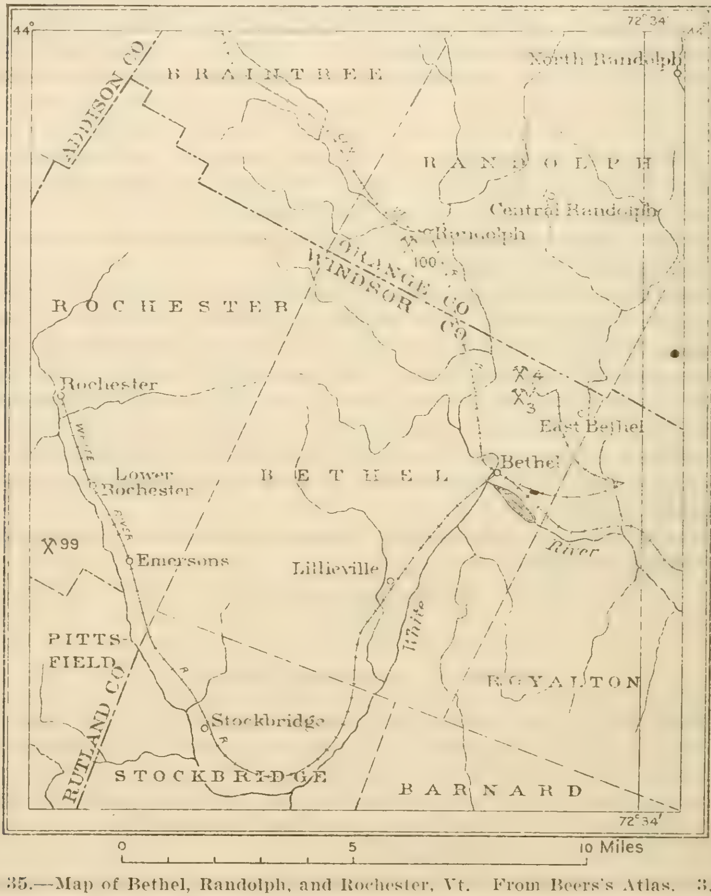

FIGURE 35.—Map of Bethel, Randolph, and Rochester, Vt. From Beers's Atlas. 3, Woodbury quarry; 4, Ellis quarry; 99, Liberty Hill quarry; 100, Beedle's prospect.

The granite of Bethel (specimens D. XXIX, 3, n, p, and 4, a, b), "Bethel White," is a quartz monzonite of slightly bluish milk-white color, with grayish spots up to 0.3 inch, and of coarse inclining to medium texture, with feldspars up to 0.4 and 0.5 inch and mica to 0.3 inch. Its constituents, in descending order of abundance, are clear colorless or rarely bluish quartz, with hairlike crystals of rutile, and with fluidal and other cavities in sheets, with rift cracks parallel thereto; bluish milk-white soda-lime feldspar (oligoclase), slightly kaolinized and micacized; clear potash feldspar (orthoclase, slightly kaolinized, with very little microcline); muscovite (white mica); and very little biotite (black mica). Accessory: Apatite, titanite, zircon, and rutile.

No magnetite or pyrite was detected. Secondary: Kaolin, a white mica, epidote, zoisite in some abundance, and very little calcite.

The stone does not effervesce with muriatic-acid test. W. T. Schaller, chemist, of this Survey, finds that it contains 0.07 per cent of CaO (lime) soluble in dilute (10 per cent) acetic acid, which indicates a content of 0.125 per cent of $CaCO_3$ (calcium carbonate), which is very slight.

A chemical analysis made for the former owners of the Ellis quarry by Charles F. McKenna, of New York, in 1903, is given here for reference.

Analysis of "Bethel granite."

Silica (SiO_2)	77.52
Alumina (Al_2O_3)	16.78
Iron oxide (FeO)	.84
Magnesia (MgO)	.32
Lime (CaO)	2.56
Soda (Na_2O)	1.21
Potash (K_2O)	.62
Loss on ignition	.33
	100.18

Three compression tests (No. 13261) made at the United States arsenal at Watertown, Mass., yielded these results (direction of rift in blocks not stated: First crack, 287,000, 301,000, 272,000 pounds; ultimate strength, 33,120, 34,350, 31,990; average, 33,153 pounds per square inch.

The stone is regarded as relatively hard by workmen. Its grade of whiteness is shown by these comparisons: The "white" of North Jay Maine, is, technically, very light gray. The "white" of West Dummerston is a trifle lighter, that of Randolph (p. 118) lighter yet, and that of Bethel still lighter, strictly white mottled with gray. Its white is more blue than that of ordinary Vermont white marble but is closely allied to its blue variety, though not its bluish gray. Owing probably to the abundance of its soda-lime feldspar, its hammered face is considerably whiter than its rough face, and the hammering also diminishes the prominence of the gray micaceous spots. It takes a high polish, but the effect is to make the mica spots more conspicuous than they are even on the rough face. The polished specimens handled by the writer do not show any pyrite or magnetite. Plate VII, *A*, representing a carved eagle, shows how the whiteness of the stone has overcome the effect of the coarseness of its texture. Although this granite is remarkably free from iron, its recent use in large edifices shows that extreme care should be exercised in handling it to prevent its absorbing rusty water, cement water, or other discoloring liquids.

Leonard P. Kinnicutt, of the Worcester Polytechnic Institute, in December, 1908, made the following determinations of absorption in "Bethel" and other granites, by W. F. Hillebrand's method, for Norcross Bros. Co., of Worcester, Mass.:

Water absorbed by 100 pounds of various granites.

	Pound.
"Bethel granite"	0.470
"New Westerly," Milford, N. H	.420
Hallowell, Maine	.405
Concord, N. H	.371
Westerly, R. I	.340
Milford, Mass	.340
Barre, Vt	.294

QUARRIES.

The **Ellis quarry** is on the east side of Christian Hill, about 2 miles north of Bethel village, in Bethel Township. (See fig. 35.) Operator, Woodbury Granite Co., Hardwick. Idle in 1922.

The granite has been described above.

The quarry, permanently opened in 1902 but in a small way many years earlier and abandoned, was estimated in 1907 as being about 1,000 feet long from north to south, and for the southern three-fifths of its length 150 feet wide, but for the remainder 400 feet wide. Its depth was 5 to 40 feet, averaging about 15 feet. Its west edge is about 80 feet higher than its east edge.

Rock structure: The sheets, 6 inches to 12 feet thick but mostly 1 to 2 feet, strike N. 10° W. and on the west side of the north end dip 30° E. but on the east side 15° E. For some not apparent reason the sheets thicken more rapidly at the east side and south end than in any other part of this or the adjoining quarry. Joint, grain, and flow courses of this and the Woodbury quarry are shown in figure 36. Joint set (A) is vertical, forms a heading at north end, recurs at two intervals of 80 feet; (B) is diagonal to the quarry and vertical, one only, about the middle of the side, but discontinuous. Compressive strain affects east-west channels more than north-south ones. Flow structure, marked at the east side and south end, consists of micaceous (muscovite) streaks up to 0.5 inch wide and sheets of discoid nodules of muscovite, also of a branching mass, 12 inches thick, largely mica, and is vertical with north course. (For details see p. 60 and Pl. III, *A*.) The rift is reported as horizontal and the grain as vertical, with N. 17° E. course, thus intersecting the flow structure at an acute angle. A few pegmatite dikes, up to 5 inches thick, have an east-west course. A quartz vein up to 1.5 inches wide strikes N. 80° W. and dips 65° S. 10° W. Some minute muscovite and quartz veins strike N. 30°–35° W. and dip 60° S. 58° W. There is one light-gray knot 10 by 8 by 2 inches; also an inclusion, 21 by 12 by 5 inches, of fine-grained syenite gneiss consisting of orthoclase, biotite, epidote, and a little oligoclase, with titanite and leucoxene but with little or no quartz. There is no rusty stain on sheet surfaces. The relations of the coarse white granite to the fine light buff-gray granite and the contact of the latter with the schist have been described on page 84 and shown in figures 8 and 9.

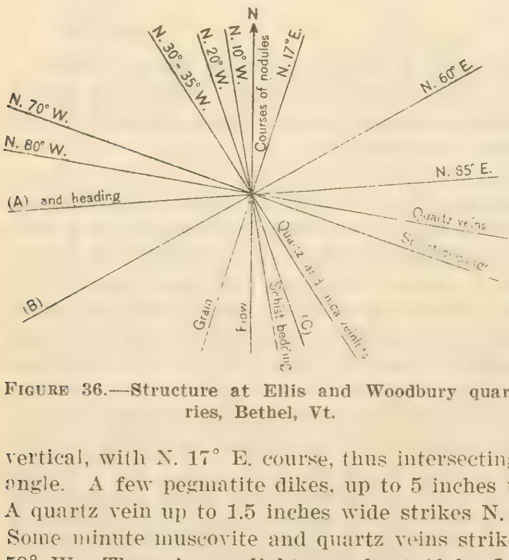

Figure 36.—Structure at Ellis and Woodbury quarries, Bethel, Vt.

The **Woodbury quarry** is 50 feet north of the Ellis quarry, on the east side and top of Christian Hill, about 2 miles north of Bethel village, in Bethel Township. (See fig. 35.) Operator, Woodbury Granite Co., Hardwick. Idle in 1922.

The granite has been described on page 156.

The quarry, opened in 1902, was estimated in 1907 as measuring about 500 feet from north to south by 200 feet across and from 5 to 30 feet in depth.

Rock structure: The sheets, 6 inches to 8 feet thick, are normal, dipping about 15° E. At a small opening about 300 feet north of the main one and

on the east side of the highest part of the hill the sheets dip 45° E. There are two sets of joints (courses shown in fig. 34)—(A), vertical, forms a 10-foot heading on the south wall between this and the Ellis quarry; (B), also vertical, is discontinuous and spaced 10 to 40 feet. An east-west compressive strain is reported by the foreman. The rift is reported as dipping less than 15° E., and the grain as vertical, with nearly east-west course. Very few of the discoid micaceous nodules referred to on page 60 occur. About 40 feet of fine buff-gray granite with schist farther east correspond to the same rocks on the west side of Ellis quarry. There is no rusty stain on sheet surfaces except near the heading.

The product of both quarries is used for buildings and monuments. Specimens: Capitol of Wisconsin at Madison; American Bank Note Building, New York (Pl. VII, *A*, represents a carving of this granite over the entrance); Theodore N. Vail residence, Morristown, N. J.; Mary Ann Brown Memorial Library, Providence, R. I.; State library and city hall, Hartford, Conn.; the post office, Union Station, and first and second stories New National Museum, Washington, D. C.; Franklin Savings Bank, Greenfield, Mass.; Congdon residence, Duluth, Minn.; Eddy Memorial, Mount Auburn Cemetery, Cambridge, Mass.; Swope Memorial, Swope Park, Kansas City, Mo.

ROCHESTER.

The Liberty Hill quarry is 3 miles south of Rochester village (the west terminal of the White River Valley Railroad), on the Rochester-Pittsfield town line. The outcrop extends into the town of Pittsfield, in Rutland County. (See fig. 35.) Operator, Liberty Hill Granite Corporation, Rochester. Quarry abandoned.

The granite (specimens D, XXIX, 99, a, b) is a quartz monzonite of slightly greenish-white color with conspicuous brilliant muscovite spots up to 0.5 inch across and of coarse texture, with feldspars up to 0.5 inch. These mica spots, being collections of mica scales, have a peculiar sheen. As they are not over 0.04 inch thick and lie with their flat sides roughly parallel, the rock has a somewhat gneissoid texture. Its constituents, in descending order of abundance, are milk-white to slightly greenish soda-lime feldspar (albite to oligoclase-albite), somewhat kaolinized and with thickly disseminated white mica scales up to 0.15 millimeter long and not a few plates of calcite; clear colorless to pale-bluish quartz, rarely with hairlike crystals of rutile, and with fluidal and other cavities in two rectangular sets of sheets, one set with many more cavities than the other; muscovite (white mica) in large flakes and aggregates. Orthoclase may be present in small amount but was not detected. There is no microcline.

An estimate of the mineral percentages by the Rosiwal method yields these results with a mesh of 0.5 inch, total linear length of 35.5 inches, and on face at right angles to gneissoid structure: Feldspar, 62.1; quartz, 29.6; muscovite, 8.3. The average diameter of all the particles obtained from the same measurements proves to be 0.34 inch; that of feldspar, 0.194 inch; quartz, 0.106 inch; and mica, 0.538 inch.

The stone effervesces with muriatic-acid test. W. T. Schaller, chemist, of this Survey, finds that it contains 1.38 per cent of CaO (lime) soluble in warm dilute (10 per cent) acetic acid, which indicates a content of 2.46 per cent of $CaCO_3$ (calcium carbonate, calcite); the presence of this mineral is also shown in thin section.

This is a building granite of extremely light greenish-gray color, with striking contrasts produced by large mica spots, the brilliancy of which on the fresh rift face is almost metallic. Whether its somewhat gneissoid texture

and its content of nearly 2.5 per cent of lime carbonate are serious obstacles to its use for building can be determined only by compression tests and by continued exposure to the weather.

In 1909 the corporation was filling a contract for the base course for the gymnasium of Dartmouth College at Hanover, N. H.

Although the outcrop is 3 miles from Rochester station, its distance from the nearest point on the railroad is only about a mile, and a siding is reported to have been constructed.

PLYMOUTH.

The State geologic map of 1861 shows a small granite area in the township of Plymouth. (See Pl. 1). Albert D. Hager[75] found the locality by tracing glacial boulders, and described its geologic relations in these words:

"We have seen but one case in the State where granite is found in the talcose schist formation, and it is a small outcrop about 60 rods [990 feet] in length and in the widest part not more than 10 rods [165 feet] in width, situated in the northern part of Plymouth. * * * The outcrop is evidently a protruded mass forced up through the schist rock. The strata of the schist are parted, and the intervening space filled with granite. At the south end of the outcrop the exact limit of the granite can be seen, the slate being parted and appearing above and below the granite. The strike of the schist over the granite is N. 10° W. with a dip from 40° to 50° E. The dip of the schist below the granite is a little less than that above. * * * Fragments of schist occur in the granite. These fragments are the same as the rock in which the granite is found. The edges and corners of the fragments are not worn, but appear to have become embedded in the matrix of granite when the latter was in a plastic state; but from this mass there are several offshoots or spurs running off at right angles across the strata of schist, as shown in the dikes in the cut and filling fissures that appear to have been made at the time the granite was erupted. These spurs, some five or six in number, vary in thickness from 1 to 10 inches."

The writer made a brief visit to this locality in June, 1916. It is about 2 miles N. 7° E. of Plymouth (Church), between the 1,500 and 1,600 foot levels as shown on the United States Geological Survey's topographic map of the Woodstock quadrangle, on the south side of Morrison Hill. It is reached by a small road running northwestward from the Pinney Hollow road at a point 1¾ miles north-northeast of Plymouth or 4½ miles southwest of Bridgewater. The outcrop is five-eighths of a mile from the main road.

The hillside has become thickly wooded since Hager's visit, and a talus hides part of the outcrop, so that only approximate measurements were practicable in the time at the writer's disposal. The length of the granite lens from northwest to southeast is not less than 450 feet, its width is 150 to 200 feet, and the height exposed on the hillside about 40 feet. The sheets, 3 to 5 and even 10 feet thick, strike N. 25° W. and dip 50° S. 65° W. Sericite schist, abounding in quartz lenses and presumably of Cambrian age, crops out northeast of and above the granite with a strike of N. 50° W. and a dip of 50° N. 40° E.[76] Southeast of the granite the schist strikes N. 40° W.

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[75] Hitchcock, C. H. and E. jr., and Hager, A. D., Report on the geology of Vermont, vol. 2, pp. 740, 741, 1861.

[76] The strike of N. 10° W. given by Hager represents the normal westerly extreme of the strike of the Cambrian schist of the region.

A. ORBICULAR GRANITE FROM ELLIS QUARRY, BETHEL, VT.

The nodules are mainly muscovite, generally corrugated, and lie with their major axes in the plane of flow structure.

B. MICA SCHIST WITH GRANITE INJECTIONS.

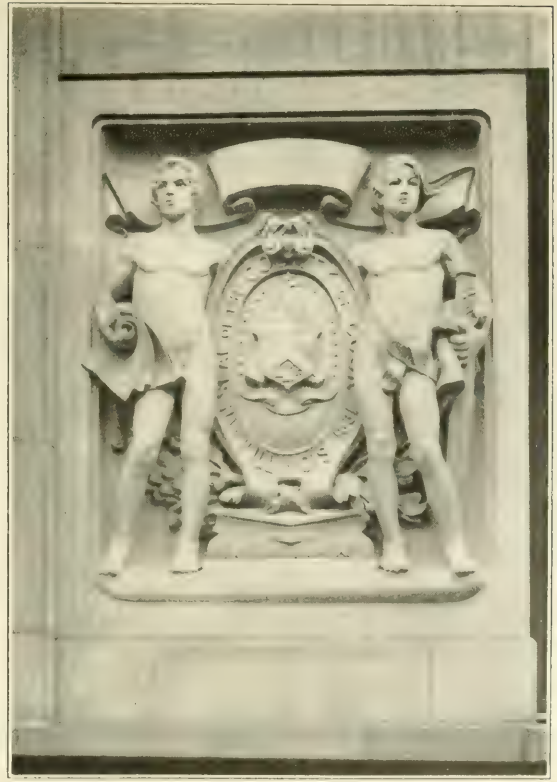
Specimen at left (6 by 5 inches) from under side of large inclusion at Boutwell quarry, Barre, Vt., shows light granite bands alternating with dark bands of schist parallel to its foliation. In specimen at right (8½ by 3 inches), from edge of inclusion at Morrison quarry, South Ryegate, Vt., the light granite forms lenses in the schist foliation.

CARVED EXEDRA OF LIGHT BARRE GRANITE.

From quarries of E. L. Smith & Co., Barre, Vt. Erected at Saco, Maine.

A. STATUE OF ROBERT BURNS AT BARRE, VT.

Light Barre granite from Barclay quarry.

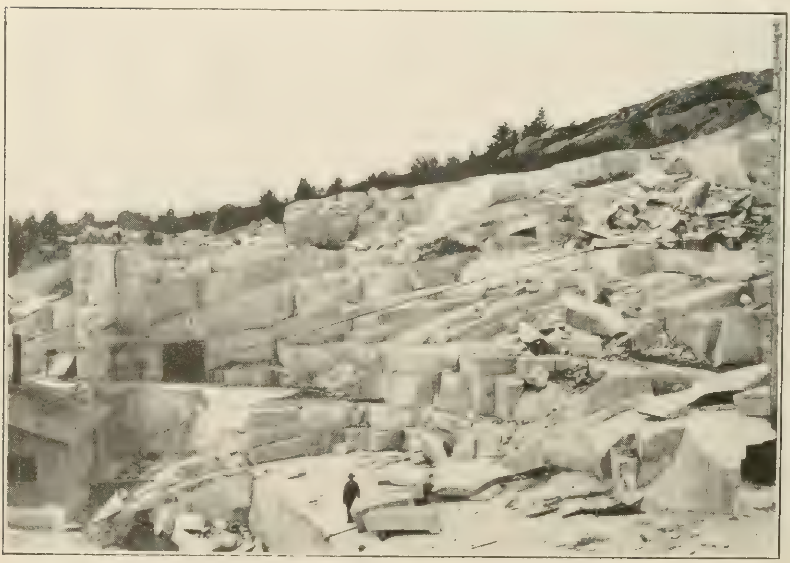


B. CARVED PANEL OF GRAY GRANITE FROM WOODBURY, VT.

Flanking entrance of Cook County courthouse, Chicago. Panel is 8 by 12 feet.

A. BLACK MOUNTAIN QUARRY, WEST DUMMERSTON, VT., SHOWING THIN SHEETS OF GRANITE FORMED SINCE THE OPENING OF THE QUARRY BY NORTH-SOUTH COMPRESSIVE STRAIN.

Hammer about 30 inches long; head 6 inches long.

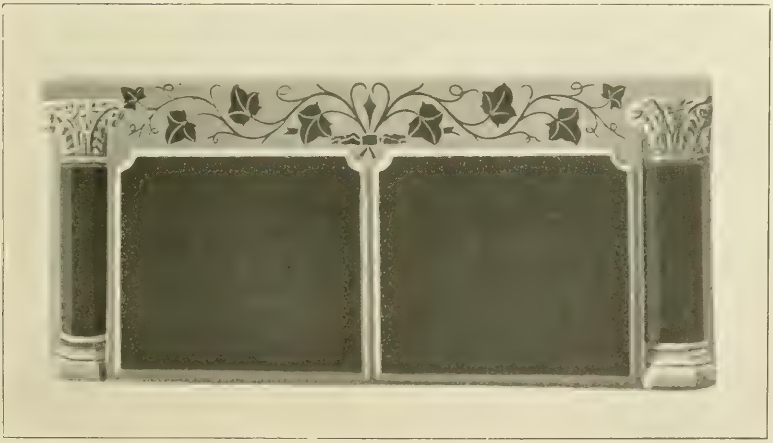


B. DOUBLE SHEET STRUCTURE AT FLETCHER QUARRY, ROBESON MOUNTAIN, WOODBURY, VT., LOOKING SOUTHWEST.

One set of sheets curves southeastward; another set, intersecting the first, dips 5°-10° S. 70° W.

A. CARVING OF COARSE WHITE QUARTZ MONZONITE FROM BETHEL, VT.

Over entrance to American Bank Note Co.'s building, New York City.



B. MONUMENT OF DARK-GREEN HORNBLENDE-AUGITE GRANITE (SYENITE) FROM MOUNT ASCUTNEY, VT.

Showing contrast between polished (black) and hammered (white, but really light gray) surfaces. Size about 5 feet 8 inches by 2 feet 6 inches.

A. CONTACT OF GRANITE (QUARTZ MONZONITE) WITH GRANITE GNEISS AT MILFORD GRANITE CO.'S ABANDONED QUARRY, MILFORD, N. H., LOOKING WEST-NORTHWEST.

Showing pegmatite dikes in gneiss and sheet structure in both rocks but not connected.

B. QUARTZ DIORITE AT ROUND POND QUARRY, MAINE.

Cut by small pegmatite dike and both crossed by a 2-foot 6-inch diabase dike parallel to one set of joints. Oxen used for hoisting.

and dips 40° N. 50° E. On the northeast the granite is in contact with the overlying schist and a small dike of fine-grained granite (probably aplite) projects from the granite into the schist a few feet. The lower southwestern contact is covered by talus in which some quarrying has been done.

The granite (specimens D, XXXVII, 145, a–d), "Plymouth white," is a quartz monzonite of fine granitic texture (grade 3) with feldspars under 0.5 centimeter (0.2 inch). The feldspars are milk-white, exceptionally remotely pinkish, and become more white on continued exposure. The quartz is very faintly smoke-colored, and the mica mostly very light. There are some discoid nodules of mica up to 0.75 inch in diameter, the granite being thus in places slightly orbicular like that of Bethel. (See p. 60.)

Its constituents, in descending order of abundance, are soda-lime feldspar (oligoclase-albite), somewhat kaolinized and micacized (many of the mica scales, being oriented, are presumably interpositions), with some epidote and calcite; quartz with rutile needles and fluidal cavities with vacuoles; potash feldspar, generally clear (microcline and orthoclase, some of the latter minutely intergrown with plagioclase); muscovite; and epidote. Some of the grains of oligoclase-albite are intergrown with microcline. Accessory, apatite and rutile. Secondary, kaolin, epidote, a white mica, and calcite.

In 1895 a small Episcopal chapel of this granite was erected in the Ottaquechee Valley, in Sherburne Township. The blocks were not squared. After 20 years of exposure the stone showed no signs of discoloration and at a little distance appeared like white marble.

Although the areal exposure of this granite is small its depth is, of course, unlimited, but its workable thickness below should be tested. Core-drilling through the schist 100 feet back from its boundary with the granite would also determine whether the schist covering may not at some points be sufficiently thin to warrant quarrying through it, and the available granite area may thus be really larger than the exposed surface of the lens.

The distance of the "Plymouth granite" to the nearest railroad, which is at Woodstock, is 13 miles by road, and the drop is to the 700-foot level, or about 850 feet.

The economic possibilities of this granite lie mainly on the very great rarity of really white granite in the United States.

WINDSOR.

TOPOGRAPHY AND GENERAL GEOLOGY.

The State map of 1861 shows a granite area in the southern parts of Windsor and West Windsor and the northern part of Weathersfield. The geology of this area has been made known by R. A. Daly [77] in an elaborate report already cited. His map (Pl. VII) shows that Mount Ascutney, which lies about 5 miles southwest of Windsor village and rises 2,800 feet above the Connecticut and 3,100 feet above sea level, consists mainly of a mass, about 2½ miles square, of greenish hornblende-augite granite (syenite) intrusive in schists, which crop out along its base, and also containing inclusions of the schist. But adjoining this syenite on the west is an area of still older gneisses, which are intruded by a mass of gabbro and diorite about 2 by 1½ miles in area. That this intrusion is older than that of the syenite is shown by the fact that dikes of the syenite penetrate it. The syenite of Mount Ascutney was itself in turn intruded by a

[77] U. S. Geol. Survey Bull. 209, 1903.

very irregular mass of biotite granite characterized by abundant dark segregations (knots) and covering about a square mile. This granite was formerly quarried, and monuments of it can be seen in the Windsor cemetery.

"WINDSOR GRANITE."

"Windsor granite," "Ascutney green" (syenite, nordmarkite phase of Daly, specimens D, XXIX, 88, a, 89, a–d) is a hornblende-augite granite which when first quarried is of dark bluish-gray color but after very brief exposure becomes dark olive-green. Its texture is medium to coarse, with feldspars up to 0.3 and 0.5 inch and black silicates to 0.2 inch. Its constituents, in descending order of abundance, as made out from the study of four thin sections, two from each quarry, are dark olive-green potash feldspar (orthoclase), minutely or obscurely intergrown with soda-lime feldspar (certainly oligoclase in two of the slides), with cleavage planes stained with limonite; dark smoky quartz with cavities (apparently without vacuoles, some of them of quartz crystal form) in streaks and sheets and crossed by intersecting cracks filled with limonite stain; green hornblende; augite, associated with or inclosed by the hornblende; biotite in very small quantity, in three slides none. Accessory: Titanite, magnetite or ilmenite, zircon, apatite, and allanite. Secondary: Limonite and white mica in the feldspar.

The cause of the change in the color of the feldspar and thus of the granite upon exposure has already been referred to (p. 76). It does not effervesce with muriatic-acid test. It is very hard and has a metallic ring under the hammer. It is brilliant in the rough from the cleavage faces of the large feldspars. Their shade is so dark that the black silicates appear only on close inspection. Owing to its extremely small content of mica it takes a very high polish, quite as high as that of the granite of Quincy. Its polished face is much darker than its rough face, but the hammered or cut face, being of medium greenish gray, is much lighter than either, so that lettering or carving stands out boldly on the polished face. (See Pl. VII, *B*.) It is best adapted for internal decorative use.

The following analysis[78] was made by W. F. Hillebrand:

Analysis of "Windsor" hornblende-augite granite (syenite).

Silica (SiO_2)		65.43
Alumina (Al_2O_3)		16.11
Ferric oxide (Fe_2O_3)	1.15	4.00
Ferrous oxide (FeO)	2.85	
Magnesia (MgO)		.40
Lime (CaO)		1.49
Soda (Na_2O)		5.00
Potash (K_2O)		5.97
Water (H_2O) above 110° C		.39
Water (H_2O) below 110° C		.19
Titanium dioxide (TiO_2)		.50
Zirconium dioxide (ZrO_2)		.11
(Phosphoric oxide) (P_2O_5)		.13
Chlorine (Cl)		.05
Fluorine (F)		.08

[78] U. S. Geol. Survey Bull. 209, p. 59, 1903.

Iron disulphide, pyrite (FeS_2)	0.07
Barium oxide (BaO)	.03
Manganese oxide (MnO)	.23
Strontium oxide (SrO)	Trace.
Lithium oxide (Li_2O)	Strong trace.
	100.18
O=F, Cl	.04
	100.14
Total sulphur (S)	.036
Specific gravity	2.659

QUARRIES.

The **Mower quarry** is on the west side of Mount Ascutney nearly 1¼ miles south of Brownsville and 580 feet above it, in West Windsor. (See map, Pl. I.) Operator, Ascutney Mountain Granite Co., Windsor. Quarry abandoned.

The granite, already described, has received the trade name of "bronze vein green."

The opening, made in 1906, was in 1907 about 50 feet square and averaged 10 feet in depth.

Rock structure: The sheets, 10 feet thick, are horizontal or dip 5° W. There are three sets of joints—(a), strike N. 85° E., vertical, spaced 2 to 18 feet; (b), strike N. 30° E., dip 75° S. 60° W., one forming the east wall; (c), strike N. 55° W., dip 65° N. 35° E., one forming the south wall. The rift is reported as vertical with N. 85° E. course, and the grain as horizontal. There is a black bronzy streak dipping 45° E., possibly of the black silicate, and showing the direction of flow. Light rusty-brown and cream-colored discoloration is 0.5 inch thick on the joint faces. In thin section some of the limonite stain of this rim proceeds clearly from particles of magnetite (or ilmenite), augite, and allanite.

The product is used mainly for dies, wainscoting, and indoor columns. Specimens: The two monolithic sarcophagi in the McKinley mausoleum at Canton, Ohio. When finished these measured 8 feet 10 inches by 4 feet 4 inches by 2 feet 6¾ inches. The covers measured 9 feet 4½ inches by 4 feet 8¾ inches by 1 foot 3¾ inches. The monument (Pl. VII, *B*) shows the contrast between cut and polished faces, the black representing what is a dark olive-green and the white what is a medium greenish gray.

The **Norcross quarry** is on the north side of Mount Ascutney on the 1,350-foot level, about 950 feet above Windsor village, a little over a mile east-southeast of Brownsville, in Windsor. (See Pl. I.) Operator, Norcross Bros. Co., Worcester, Mass. This quarry has been operated only occasionally and is now abandoned.

The granite has been described on page 162.

The quarry is about 200 feet from east to west by 40 feet across and has a working face 60 feet high on the south, with a rugged cliff above it, making a total face of 80 to 90 feet above the quarry bottom and road.

Rock structure: The sheets, 2 to 10 feet thick, are horizontal or dip 10° N. There are two sets of joints—(a), strike N. 75° to 80° E., vertical, spaced 2 to 10 feet; (b), strike N. 5° W., vertical, spaced 5 to 30 feet, with a heading 10 feet wide through the center of the quarry. The splitting has been done in the direction of (a), which is the rift direction at the Mower quarry and presumably here also. There are many dark streaks. A 4-foot dike crosses the quarry parallel to and within heading (b). This appears to be also a horn-

blende-biotite granite. It is of medium greenish-gray color and of medium inclining to fine texture, with feldspars mostly under 0.2 inch, rarely 0.4 inch, and black silicates mostly under 0.1 inch. Its constituents, in descending order of abundance, are greenish medium-gray potash feldspar with obscurely intergrown soda-lime feldspar, kaolinized; smoky quartz, more of it than in the adjacent granite; finely striated soda-lime feldspar (oligoclase-albite); hornblende; a little biotite. Accessory: Magnetite or ilmenite, titanite, and allanite. Secondary: Kaolin.

The sheet surfaces, chiefly owing to the kaolinization of the feldspar, are discolored to a medium, slightly greenish gray, and the joint faces are similarly discolored but have a limonitic border. The discoloration is from 1 to 1.5 inches thick.

Transportation by cart to rail at Windsor.

The product has been used for monumental and decorative purposes. Specimens: Sixteen polished columns (24 feet 9½ inches by 3 feet 7 inches) in Columbia University Library, New York; monument to General Gómez in Cuba; a die in the Bennington monument; 34 large columns in the Bank of Montreal; columns and die of W. C. T. U. fountain, Orange, Mass.

NEW HAMPSHIRE.

DISTRIBUTION OF GRANITE-QUARRYING CENTERS.

Plate I shows the location of the granite-quarrying centers and of the isolated quarries in New Hampshire.

GEOLOGIC RELATIONS OF NEW HAMPSHIRE GRANITES.

In view of the transition from the older views as to the origin of granite to the more matured views of to-day and also the substitution of more exhaustive methods of geologic exploration for the necessarily more cursory methods of the past, it does not seem advisable to undertake to transcribe here an outline of the complex and uncertain geologic relations of New Hampshire granites from geologic literature. Instead of that, a summary of the geologic observations made at all the quarries of each quarrying center or district will be given. These facts will ultimately fit into the final geologic mapping and history of the State, whatever these may prove to be.

THE QUARRIES, THEIR GRANITE AND FINISHED PRODUCT.

CARROLL COUNTY.

CONWAY.

TOPOGRAPHY.

The Conway quarries are near North Conway, some of them on the east and west sides of the Saco Valley. The Redstone quarries, on the east, are at the south foot of a series of summits ranging from 1,550 to 2,375 feet above sea level (Black Cap, Middle Mountain, and Rattlesnake Mountain), known collectively as the Green Hills; and the White Mountain quarry on the west, is on a 765-foot lenticular granite mass lying about 2 miles S. 25°–45°

E. of the granite domes known as White Horse and Cathedral ledges. Also belonging to this group of quarries is the Fletcher quarry, in the town of Madison, which adjoins Conway on the south. This quarry lies southeast of Moat Mountain and about 2½ miles southwest of Conway Corners. (See fig. 37.)

GEOLOGY OF THE QUARRIES.

The geologic feature of general interest in Conway granites is their marked rift and grain and the manifest relation of these to the sheets of microscopic cavities, as shown in figure 1 and described on page 17. The rift is reported

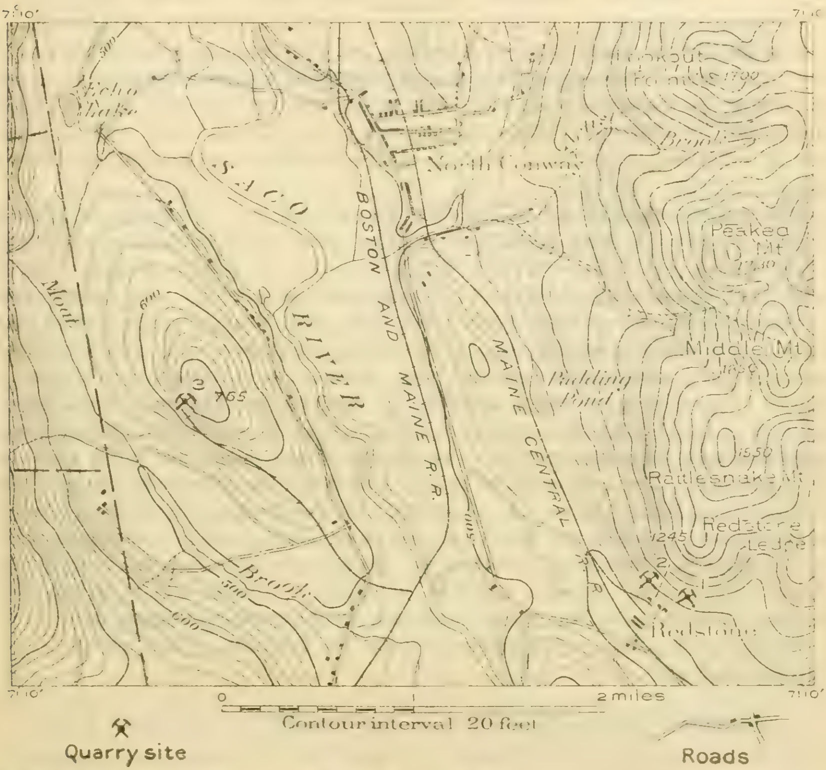


FIGURE 37.—Map of part of Conway, N. H., showing location of granite quarries. 1, Redstone red granite quarry; 2, Redstone green granite quarry; 3, White Mountain quarry. The boundary between pink and green granite is shown by dotted line.

as uniformly horizontal, and the grain as vertical with N. 80°–90° W. course. Another feature is the contiguity of a yellowish-green biotite-hornblende granite to the pink biotite granite at Redstone. (See fig. 37.) Between the 500 and 800 foot levels the boundary has a N. 23° E. course and is said to continue in that direction toward Rattlesnake Mountain. Although the feldspars of both these granites are equally kaolinized, their original colors probably differed as greatly as their present ones. The feldspar of the green stone seems to have been a bluish gray and that of the pink probably clear and colorless or slightly pinkish. Their present colors are due to the formation of limonite in the green and hematite in the pink. This limonite is

largely traceable to somewhat abundant allanite and to the hornblende; the hematite may be attributed to the oxidation of magnetite or of ferrite in infinitesimal particles in the feldspars. These two granites side by side represent originally different materials, and the line of their contact indicates the direction of their flow. A 20 by 30 foot segregation or dike of porphyritic biotite-hornblende granite, and geodes, coated internally with calcite rhombs and chlorite, should also be noted as occurring at the red quarry. The joint systems at the four quarries have courses of N. 70°–90° W., N. 35° W., N. 15° E., and N. 30° E. The sheets dip gently east and west from the axis of the ridge.

QUARRIES.

The **Redstone pink quarry** is in the town of Conway, about 3 miles S. 35° E. of North Conway, on the base of Redstone Ledge, one-third of a mile N. 50° E. of Redstone station on the Maine Central Railroad, and 180 feet above it. (See North Conway topographic map, U. S. Geol. Survey; also fig. 37.) Operator, Maine & New Hampshire Granite Corporation, North Jay, Maine.

The granite (specimens D, XXVIII, 35, a, b, j, k), "Conway pink," is a biotite granite of light pinkish-gray color with large dark-gray and small black spots. Its texture is even grained, coarse, and with feldspars up to 0.75 inch, exceptionally 1.25, and black mica up to 0.3 inch. Its constituents, in descending order of abundance, are a light pink, nearly opaque potash feldspar (orthoclase, mostly twinned), minutely intergrown with soda-lime feldspar; smoky amethystine quartz with cavities up to 0.012 millimeter, in sheets, intersecting at right angles and parallel to rift and grain cracks (see fig. 1 and p. 17); translucent very light gray to milk-white striated soda-lime feldspar (oligoclase-albite); and biotite (black mica), but little of which is chloritized. The orthoclase is much kaolinized; the oligoclase less so. The orthoclase in places surrounds oligoclase; in one specimen a small crystal of orthoclase is inclosed by oligoclase, and that has a zone of orthoclase about it. Accessory: Magnetite (ilmenite?), pyrite, apatite, fluorite, and zircon. Secondary: Kaolin, chlorite, titanite (leucoxene), calcite, and hematite stain mostly combined with the kaolin and only visible under incident light.

Estimates of the mineral percentages by the Rosiwal method yield the following results:

Estimated mineral percentages in "red granite" of Redstone, N. H.

	1	2	3
Feldspar	62.60	68.00	65.30
Quartz	31.00	26.30	28.65
Mica (biotite)	6.40	5.70	5.55
	100.00	100.00	

1. Specimen cut at right angles to both rift and grain; mesh 0.8 inch, total linear length 39.2 inches.
2. Specimen cut parallel to rift showing larger feldspars; mesh 1.2 inch, total linear length 28.8 inches.
3. Average of both estimates.

An analysis of this granite, made for the firm in 1898 by Franklin C. Robinson, State assayer of Maine, is here given merely for reference.

Analysis of "red granite" from Redstone, N. H.

Silica (SiO_2)	71.44
Alumina (Al_2O_3)	14.72
Iron sesquioxide (Fe_2O_3)	2.39
Iron oxide (FeO)	.46
(Total iron oxides, 2.85.)	
Magnesia (MgO)	.96
Soda (Na_2O)	7.66
Potash (K_2O)	.89
Rare elements, mostly titanium and zirconium dioxides (TiO_2 and ZrO_2)	.78
Manganese, sulphur, calcium, phosphates	Traces.
Loss at red heat (mostly water)	.61
	99.91

Specific gravity, 2.635.

W. T. Schaller, a chemist of this Survey, finds that this granite contains 0.16 per cent of CaO (lime), soluble in hot dilute acetic acid, which indicates a content of 0.267 per cent of $CaCO_3$ (calcium carbonate); the presence of this carbonate is also shown by the microscope.

A test made at the United States arsenal at Watertown, Mass., in 1887, gives this granite a compressive strength of 22,370 pounds to the square inch.

The stone takes a high polish, but the large size of its mica scales is not favorable to the durability of the polish under long-continued outdoor exposure. Polished faces show some magnetite. As the relative amount of gray to pink feldspar is small, the contrast is mostly between the pink feldspar and the smoky amethystine quartz, which is very pleasing. The minor spots of black mica give it still more character. This is a constructional granite but is also, by its polish and contrasts, adapted to internal decorative uses.

The quarry, opened about 1887, measured in 1906 about 500 feet from east to west by 300 feet across and from 30 to 80 feet deep, with a working face 80 feet high on the north.

Rock structure: The sheets, 4 to 30 feet thick, are normal and arch across the axis of the hill, dipping 15° E. in this quarry. There are three sets of joints—(a), strike east, vertical, spaced 5 to 40 feet, not everywhere continuous; (b), strike N. 35° W., dip 80° S., forms a heading in the west part but does not recur; (c), strike N. 15° E., vertical, recurs at 160 feet. The rift is reported as horizontal, and the grain as vertical with east-west course. Both are marked and appear as delicate cracks in the quartz particles on polished surfaces parallel to the "hard way." This interesting textural feature is fully discussed on page 17 and is illustrated in figure 1. There are small dikes of deep pinkish aplite (fine textured, particles 0.185–0.555 millimeter) consisting of pinkish orthoclase, clear quartz, clear oligoclase, and very little biotite, with secondary muscovite and hematite stain. In the eastern part of quarry is a mass about 30 feet from north to south by 20 feet from east to west and with an exposed depth of 10 feet, which may be a very large knot or possibly the upper part of a dike oval in cross section. Streaks of black mica 10 feet long radiate from its upper surface, also irregular pegmatitic bands with small dark-gray knots. Its matrix (particles 0.074 to 0.59 millimeter) is of medium purplish-gray color and incloses porphyritic light pinkish feldspars up to 0.7 inch, light smoky quartz to 0.03 inch, and black silicate to 0.2 inch. The matrix itself consists of orthoclase, quartz, oligoclase-albite,

hornblende, and biotite, with accessory magnetite, apatite, fluorite, titanite, and zircon. The large feldspars are orthoclase with intergrown oligoclase and quartz.

There are elliptical and spherical knots from 0.5 inch to 14 inches in diameter of exceedingly fine, very dark gray, large biotitic material with sparse porphyritic feldspars. Lenses of pegmatite up to 2 feet by 6 inches also occur, and lenticular geodes, mainly of intergrown quartz and feldspar surrounded by a half-inch band of aplite. These geodes are lined with crystals of smoky amethystine quartz and orthoclase incrusted with chlorite and calcite. Some obtuse rhombs of calcite are 0.5 inch wide. Joint (c) is coated with epidote and chlorite, and the granite for 0.5 inch back of it is much altered to kaolin and mica and stained by hematite and limonite. (See p. 83.) Rusty stain is an inch thick along sheet surfaces, but up to 4 inches along the joints.

The product is used mainly for buildings. Specimens: First National Bank, Chicago; First National Bank and Hamilton County courthouse, Cincinnati; Wisconsin Telephone Co.'s building, Milwaukee, Wis.; Franklin Savings Bank and McAlpin Hotel, New York; Temple Bar Building, Brooklyn; Union Station, Pittsburgh; city hall, Lowell, Mass.; base of Longfellow monument, Portland, Me.; State library, Concord, N. H. (the pilasters and trimmings of "Concord granite," the columns at entrance of polished green granite from the next quarry, and the rest of "Conway pink").

The **Redstone green quarry**, operated by the same company, is about 800 feet west-northwest of the pink quarry, described above, and about 140 feet above Redstone station. (See fig. 37.)

The granite (specimens D, XXVIII, 36, a, b, c), "Redstone green granite," is a biotite-hornblende granite of dark-yellow greenish color with black spots. Its texture is even grained, coarse, with feldspars up to 0.8 inch and mica to 0.3 inch. Its constituents, in descending order of abundance, are medium-gray potash feldspar (orthoclase) with some yellow-green stained cleavage faces (this feldspar is always minutely intergrown with lime-soda feldspar, oligoclase-albite, some of it is twinned, and it is all much kaolinized); dark yellow-green smoky quartz with cavities in two or three sets of intersecting sheets with rift and grain cracks parallel to two of them and in places coinciding with them (see p. 17); very little separate soda-lime feldspar (oligoclase-albite), slightly micacized; biotite (black mica) and hornblende, some of it corroded. Accessory: Magnetite (ilmenite?), fluorite, allanite (mostly in biotite), and zircon. Secondary: Kaolin, a white mica, calcite, epidote in veinlets, chlorite, and limonite.

An estimate of the mineral percentages, obtained by the Rosiwal method, yields the following results with 0.5-inch mesh and total linear length of 71 inches: Feldspar, 54.79; quartz, 38.26; mica (biotite), 6.95.

An analysis made for the firm by Franklin C. Robinson, State assayer of Maine, in 1899, is given here merely for reference:

Analysis of "green granite" from Redstone, N. H.

Silica (SiO_2)	70.42
Alumina (Al_2O_3)	14.64
Iron sesquioxide (Fe_2O_3)	1.54
Iron oxide (FeO)	2.34
(Total iron oxides, 3.88.)	
Magnesia (MgO)	1.20
Soda (Na_2O)	7.80
Potash (K_2O)	.71

Rare elements, mostly titanium and zirconium dioxides (TiO_2 and ZrO_2)	0.48
Manganese, sulphur, calcium, and phosphates	Traces.
Loss at red heat, mostly water	.61
	99.74

Specific gravity, 2.634.

It will be noticed, on comparing the amounts of iron oxides in this and the red granite (p. 167), that this exceeds the other by 1 per cent, which is attributable to its larger content of hornblende and allanite and of the limonite proceeding therefrom.

When first quarried this stone is more greenish than after a few years' exposure, when its feldspars become more grayish, but its general color is even then still markedly greenish. The cause of this change is not apparent, for organic acids do not reach the quarried blocks. It takes a high polish, but its large mica plates furnish vulnerable points of attack by the weather under prolonged exposure. The polished face shows a little magnetite. The contrasts are weaker than in the red granite, owing to the darker shade of its feldspar. Whether in the rough or polished, its color is striking. Though not unsuitable for purposes of construction, it is a coarse decorative granite well adapted for sheltered positions.

The quarry, opened about 1887, measured in 1906 about 150 feet north to south by 100 feet across and up to 50 feet in depth, which is the height of the working face on the north. It is worked at intervals only.

The sheets, 11 inches to 14 feet thick, dip about 15° W. Joint sets, rift, and grain are the same as in the red quarry.

The product is used for buildings and polished columns. Specimens: Union Arcade Building, Pittsburgh, Pa.; front of the first three stories of Fidelity Mutual Life Insurance Building, Philadelphia; interior columns, post office, Washington, D. C.; exterior columns, Dime Savings Bank, Detroit, Mich.; interior columns, Missouri capitol, Jefferson City, Mo.; exterior columns, First National Bank, Bridgeport, Conn.; also in Baxter Building, Portland, Maine.

The White Mountain quarry is in the town of Conway, 1¾ miles southwest of North Conway, on the west side of a hill between Saco River and Moat Brook, southeast of White Horse Ledge. (See fig. 37.) Owner, Henry A. Hitner's Sons Co., Pennsylvania Building, Philadelphia.

The granite (specimens D, XXVIII, 38, a, b) is a biotite granite of medium pinkish buff-gray color with black spots. Its texture is even grained, coarse, with feldspars up to 0.8 inch and mica to 0.3 inch. Its constituents, in descending order of abundance, are pinkish-buff potash feldspar (orthoclase) in twins and minutely intergrown with soda-lime feldspar (oligoclase-albite), also intergrown with quartz and kaolinized; amethystine quartz with cavities in sheets intersecting at right angles, those in the rift direction being very close together; slightly greenish gray soda-lime feldspar (oligoclase), also intergrown with quartz, kaolinized, and partly micacized, in places inclosed in orthoclase; biotite (black mica), some of it chloritized. Accessory: Fluorite, allanite, zircon. Secondary: Kaolin, a white mica, chlorite, and limonite and hematite stain.

This is a coarse constructional granite with good rift.

The quarry, not operated since December 1, 1903, lies between the 645 and 735 foot levels, measures about 400 feet N. 75° W. by 250 feet across and from

35 to 90 feet in depth. The top of the working face is 30 feet below the top of the hill.

Rock structure: The sheets, from 3 to 30 feet thick, are horizontal or dip low north and also south. Joints (a) strike N. 30° E., dip 60° N. and 90°, spaced 20 to 70 feet. Joints (b) strike N. 70°–80° W., vertical, spaced 2 to 50 feet.

Rusty stain is from 1 to 8 inches thick on the sheets and up to 2 feet along the joints.

Transportation by private siding, 1¾ miles long, from main line of Boston & Maine Railroad. (See fig. 37.)

This quarry was opened by the contractors for the Boston dry dock at the Charlestown Navy Yard, in which the stone was used.

MADISON.

The **Fletcher quarry** is in the town of Madison, about 2½ miles southwest of Conway and 1 mile about west of the main line of the Boston & Maine Railroad. (See Pl. I.)

The granite (specimens D, XXVIII, 37, b, d)—the more pinkish variety—is a biotite granite of light pinkish-gray color, mottled with dark purplish gray and with small black spots. Its texture is even grained, coarse, with feldspars up to 0.7 inch and mica to 0.2 inch. Its constituents, in descending order of abundance, are a light pinkish-gray potash feldspar (orthoclase, mostly twinned), minutely intergrown with soda-lime feldspare (oligoclase-albite) and considerably kaolinized; dark amethystine smoky quartz with cavities; translucent slightly greenish-white striated soda-lime feldspar (oligoclase), partly micacized; and biotite (black mica), some of it chloritized. Accessory: Magnetite and allanite. Secondary: Kaolin, a white mica, and chlorite.

An estimate of the mineral percentages, by the Rosiwal method yields the following results with mesh of 0.5 inch and total linear length of 20 inches: Feldspars, 67.20; quartz, 28.60; mica (biotite), 4.20.

E. C. Sullivan, a chemist of this Survey, finds that this granite contains 0.25 per cent of CaO (lime) soluble in hot dilute acetic acid, which indicates a content of 0.44 per cent of $CaCO_3$ (lime carbonate).

This is a coarse-textured constructional granite of warm tint, possessing marked contrasts of color, which come out strongly on the polished face (delicate pink, mottled with purplish smoke and dotted with black). The somewhat large mica scales are not favorable to the durability of the polish under long-continued outdoor exposure.

The less pinkish variety (specimen 37, a) is like the other except in that the orthoclase is more nearly cream-colored. Apatite and zircon appear among its accessory minerals. Its contrasts are, if anything, a trifle more marked than those of the other.

The quarry, opened between 1888 and 1891, abandoned before 1917, is at the east foot of a granite bluff 200 feet high, which also has a steep south side. It is about 500 feet square, with an extension on the bluff where there is a working face 100 feet high. Its depth is from 15 to 50 feet.

Rock structure: The sheets, 2 to 20 feet thick, are horizontal but dip 10° E. to ENE. There are two sets of joints—(a), strike N. 80° W., vertical spaced 5 to 100 feet, forms a 10-foot heading in the north half of quarry and another at the north wall; (b), strike N. 15° E., vertical, spaced 5 to 100 feet, forms a heading on the east side. The rift is reported as horizontal and the grain as vertical, with N. 80° W. course. The pinkish variety oc-

curs on the south side, and the lighter variety on the north. Rare granitic dikes, 1 to 6 inches wide, consist of a groundmass of medium-gray shade and fine to medium texture (orthoclase, microcline, oligoclase-albite, quartz, and biotite), spangled with biotite and with porphyritic pinkish feldspars up to 0.4 inch. Rusty stain is from 1 to 4 inches thick on upper sheets, decreasing below. Joint faces are coated with epidote.

Transportation, by a siding 1 mile to main line of Boston & Maine Railroad. In 1906 the stone was used for certain piers on the Boston & Maine Prison Point Street Bridge, at East Cambridge, Mass., and also for a bridge at South Acton, Mass. Specimen monument: Dudley Porter memorial fountain, Haverhill. Mass.

CHESHIRE COUNTY.

FITZWILLIAM DISTRICT.

GEOLOGIC RELATIONS.

The granite of the Fitzwilliam district, Cheshire County, occurs in an area extending a little into the State of Massachusetts, designated by Emerson[79] on the geologic map of that State "Fitzwilliam granite (white muscovite-biotite granite)," and regarded by him as of late Carboniferous or post-Carboniferous age.

QUARRIES.

The **Webb Fitzwilliam quarry** is half a mile south of Fitzwilliam Depot, in Fitzwilliam Township. (See Monadnock topographic map, U. S. Geol. Survey.) Operator, Webb Granite & Construction Co., 40 Crescent Street, Worcester, Mass.

The granite (specimen D, XXX, 66, a), "Fitzwilliam Webb," is a muscovite-biotite granite of light, very bluish gray color and of even-grained fine texture, with feldspars and micas under 0.2 inch. Its constituents, in descending order of abundance, are clear, colorless to translucent bluish potash feldspar (microcline and orthoclase), slightly kaolinized; clear colorless quartz with cavities and hairlike crystals of rutile; clear to milk-white soda-lime feldspar (oligoclase), some of it slightly kaolinized and micacized; muscovite (white mica) in large scales; and biotite (black mica) in more abundant and much smaller scales. Accessory: Magnetite (very little), apatite, rutile. Secondary: Kaolin, a white mica. No effervescence with muriatic-acid test.

The quarry, opened before 1829, measured in 1909 about 1,300 feet in a N. 50° E. direction by 200 feet in width for half of its length and by 250 feet for the rest, and from 6 to 35 feet in depth.

Rock structure: The sheets are 6 inches thick at the top and 3 feet at the bottom, the greater part, however, being thin ones. They dip 15° NW. at the northwest side but turn, dipping northeast on the northeast side of the hill. The general structure of the hill is thus that of either a dome or an anticline. There are only five joints—set (a), of four joints, near the northeast end of the quarry, strike N. 20° W., dip 90° or steep, spaced 5, 20, and 100 feet; (b), near the southwest end of the quarry, strike N. 40° E., dip 70° N. 50° W. The rift is reported as striking N. 55°E. and dipping 35°–40° N. 35° W., and the grain as dipping 80° S. 35° E. In working the rock is split along the grain. Many dikes of garnetiferous pegmatite, from an inch to 2 feet thick, strike north or north-northwest and dip 90° or 20° E. In places the pegmatite is associated with

[79] Emerson, B. K., Geology of Massachusetts and Rhode Island: U. S. Geol. Survey Bull. 597, pl. 10, p. 238, 1917.

aplite. Small aplite dikes, 1 to 2 feet apart, strike east. All these dikes throw considerable stone into the second class. No rusty stain nor segregations were observed.

Transportation, by a 7,000-foot siding to Fitzwilliam Depot, besides 1,500 feet of subsidiary siding in the quarry.

The product was used mainly for buildings and monuments. Specimens: City hall, Newark, N. J.; approaches and base of First Church of Christ, Scientist, Boston. The smaller sheets were used for paving.

This quarry was abandoned before 1917.

The **Victoria White** (formerly Silver White) **quarry** is a quarter of a mile northeast of Fitzwilliam Depot, in Fitzwilliam Township. (See Monadnock topographic map, U. S. Geol. Survey.) Operator, Milford Pink-Victoria White Granite Co., Milford, Mass.

The granite (specimens D, XXX, 68, a, b), "Victoria white," is a biotite-muscovite granite of light bluish-gray color and of even-grained, very fine texture, with feldspars under 0.1 inch and micas to about 0.05 inch. Its constituents, in descending order of abundance, are clear colorless to translucent bluish potash feldspar (orthoclase and microcline); very light smoky quartz with cavities and hairlike crystals of rutile; clear to milk-white soda-lime feldspar (oligoclase), very little kaolinized, some small mica crystals; biotite (black mica); muscovite (white mica). Accessory: Rutile. Secondary: Kaolin, calcite. Effervesces slightly with muriatic-acid test. Polished face shows neither pyrite nor magnetite.

An estimate of the mineral percentages by the application of the Rosiwal method to a camera lucida drawing of a thin section enlarged 40 diameters yields these results with a mesh of 1.8 and a total linear length of 43.2 inches:

Estimated mineral percentages in Fitzwilliam granite from Victoria White quarry.

Quartz		43.66
Potash feldspar (microcline and orthoclase)	32.22	45.74
Soda-lime feldspar (oligoclase)	13.52	
Black mica (biotite)	5.88	10.60
White mica (muscovite)	4.72	
		100.00

The average diameter of the particles, obtained from the same calculation, is 0.00668 inch.

Prof. Leonard P. Kinnicutt, of the Worcester Polytechnic Institute, by a test made December 11, 1908, for the Norcross Bros. Co. in Worcester, found that 100 pounds of Fitzwilliam granite quarried at this or the Snow Flake quarry absorbed 0.382 pound of water.

This is a delicate bluish-gray fine-grained stone, well adapted for fine work. Its particles are so fine and its minerals so evenly distributed that aside from a fine mottling, visible only near by, its color is uniform. It takes a good polish.

The quarry, opened about 1904, was in 1909 about 300 feet square and 40 feet deep.

Rock structure: The sheets consist of short lenses at the surface but are not well marked below. The quarry is probably near the lower limit of sheet structure. There are no joints, but here and there a fracture crosses one sheet only. One such fracture strikes N. 40° E. and dips 60° N. 50° W. The

rift is reported as horizontal and the grain as vertical, with a nearly east-west course. Pegmatite dikes up to 1 foot thick strike N. 30° W. and N. 60° W., with steep dips. Biotitic segregations are rare and up to 4 inches across. There is little or no rusty stain on sheet surfaces.

The product is used for monuments. Specimens: Pylon monuments and approach to Manhattan Bridge, Brooklyn Plaza; Katherine Sefton Page Memorial, Auburn, N. Y.; L. C. Smith mausoleum, Syracuse, N. Y.; industrial monument by Zolnay, New Bedford, Mass.; C. W. Post mausoleum, Oak Hill Cemetery, Battle Creek, Mich.; Lilly exedra, Anderson, Ind.

The **Snow Flake quarry** is two-fifths of a mile northeast of Fitzwilliam Depot and three-fourths of a mile south of Fitzwilliam village, in Fitzwilliam Township. (See Monadnock topographic map, U. S. Geol. Survey.) Owner, Victoria White Granite Co., Keene, N. H.

The granite (specimen D, XXX, 67, a), "Snow Flake," is a biotite-muscovite granite of light inclining to medium gray shade and of porphyritic texture, with fine matrix (micas under 0.1 inch) and feldspars to 0.5 inch. Its constituents, in descending order of abundance, are faintly greenish clear potash feldspar (microcline in twins with crush borders, also orthoclase), some of the microcline intergrown with quartz, some slightly kaolinized; light smoky quartz with cavities, generally in sheets, and hairlike crystals of rutile; clear to milk-white soda-lime feldspar (oligoclase-albite), some of it minutely intergrown with quartz (vermicular structure), some of it a little kaolinized; biotite (black mica); and muscovite (white mica). Accessory: Apatite, zircon, rutile. Secondary: Kaolin, limonite from biotite. No effervescence with muriatic-acid test.

The fineness of the mica deprives the stone of strong contrasts, and the porphyritic texture is discernible only on close inspection.

The quarry, opened between 1885 and 1887, was in 1909 about 300 feet square and 40 to 70 feet deep.

Rock structure: The sheets, 10 to 20 feet thick, are about horizontal but irregular. There is but one joint. The rift is reported as horizontal and the grain as vertical, with about east-west course.

Transportation, by siding to Fitzwilliam Depot.

The product has been used for buildings.

The following are specimens of the combined product of this and the Victoria White quarry: Art Museum, Toledo, Ohio; law building of University of Iowa, Iowa City; post offices at Muskegon, Mich., Chippewa Falls, Wis., Grand Island, Nebr., Decatur, Ill., Bedford, Ind., Mayfield, Ky., Devils Lake, N. Dak., Allentown, Pa., and Ithaca, N. Y.; and Wysong residence, corner Seventy-sixth Street and Seventh Avenue, New York City.

This quarry has not been operated since it passed into the hands of its present owners.

The **Emerson quarry** is 2 miles northeast of Fitzwilliam Depot, in Fitzwilliam Township. Operator, Paul Drewes, Fitzwilliam Depot. Idle in 1922. (See Monadnock topographic map, U. S. Geol. Survey.)

The granite is a muscovite-biotite granite, a trifle lighter and coarser textured than the "Victoria white" (p. 172).

The quarry measures about 1,000 feet square and 50 to 70 feet in depth.

The **Yon quarry** is about 1¼ miles south-southeast of Fitzwilliam Depot and half a mile east of South Pond (Laurel Lake), in Fitzwilliam Township. (See Winchendon topographic map, U. S. Geol. Survey.) Operator, Edward Yon & Son, Fitzwilliam Depot.

The granite, "white," resembles the other light bluish-gray muscovite-biotite granites of this township.

The quarry, opened about 1897, has been regularly operated since 1908.

The product is used mainly for buildings and monuments, also for curbing.

The **Thompson quarry** is about 2 miles northeast of Fitzwilliam Depot, in Fitzwilliam Township. (See Monadnock topographic map, U. S. Geol. Survey.) Operator, E. M. Thompson, Fitzwilliam Depot.

The quarry was opened in 1900.

The granite is a muscovite-biotite granite of medium grayish shade and fine even-grained texture with feldspars up to 0.2 inch, muscovite and biotite to 0.1 inch.

Its constituents, in descending order of abundance, are clear colorless potash feldspar (orthoclase and microcline), with inclusions of plagioclase and intergrown with quartz; pale smoky quartz with rutile needles; clear to milk-white soda-lime feldspar (probably oligoclase); muscovite and biotite. No effervescence with muriatic-acid test.

The **Webb Marlboro quarry** is $1\frac{1}{4}$ miles north-northeast of Webb station (Marlboro depot), in Marlboro Township. (See Monadnock topographic map, U. S. Geol. Survey.) Operator, Hildreth Granite Co., Boston, Mass.

The granite (specimen D, XXX, 69, a), "Marlboro," is a biotite-muscovite granite of light inclining to medium, very bluish gray color and of even-grained fine texture, with feldspars and micas up to 0.2 inch. Its constituents, in descending order of abundance, are clear colorless to translucent bluish potash feldspar (microcline), intergrown with quartz, circular in cross section and slightly kaolinized; clear colorless quartz with cavities in sheets and hairlike crystals of rutile; milk-white soda-lime feldspar (oligoclase), somewhat kaolinized and with small plates of muscovite; biotite (black mica); muscovite (white mica). Accessory: Apatite, zircon, rutile. Secondary: Kaolin, calcite. Effervesces with muriatic-acid test.

The quarry, opened before 1849, was originally about 950 feet long by about 700 feet wide but in 1909 measured about 750 feet in a north-northeasterly direction by 200 feet across and average 50 feet in depth.

Rock structure: The sheets, 6 inches to 6 feet thick, but not over 2 feet in the upper half of the quarry, are normal and horizontal, but dip low north-northeast at the north end of the quarry and turn to dip low south-southwest at the south end. The thinness of the sheets and the compressive strain prevent channeling, so dynamite is used. Two vertical joints near the north end, with N. 60° E. strike, extend off and on for 50 feet. On the extreme east side a joint striking N. 50° E. and dipping 50° NW. extends only 100 feet. Flow structure is very marked on sheet surfaces at the west side. It consists of alternately more or less biotitic planes striking N. 30° E. but also curving, varying much in width and resembling a gneiss foliation. On the east side flow structure has a N. 35° E. course. There is an inclusion or an irregular biotitic flowage band, $4\frac{1}{2}$ feet long, 1 foot wide, and oval in cross section. The rift is reported as horizontal and the grain as vertical, with N. 22° E. course. A thick pegmatite dike crosses the center of the quarry with N. 55° W. course. There are smaller pegmatite dikes and streaks of like course in the northern half of the quarry. There is no rusty stain on sheet surfaces.

Transportation, by 4 miles of siding from Webb station.

The product is used mainly for buildings, curbing, and paving. Specimens: The lower seven stories of the Marshall Field Building, Chicago; First Congregational Church, Nashua, N. H.; Soldiers' monument, Fitzwilliam village, N. H.

The **Troy quarry** is three-fourths of a mile east-southeast of Troy station, in Troy Township. (See Monadnock topographic map, U. S. Geol. Survey.) Quarry abandoned.

The granite (specimen D, XXX, 70, a), "Troy white," is a muscovite-biotite granite of light inclining to medium bluish-gray color and of even-grained fine texture, with feldspars under 0.2 inch and mica to 0.1 inch. Its constituents, in descending order of abundance, are clear bluish potash feldspar (microcline, generally in twins, intergrown with quartz, circular in cross section, also orthoclase); clear colorless quartz with hairlike crystals of rutile and cavities in sheets; milk-white soda-lime feldspar (oligoclase-albite), some of it minutely intergrown with quartz, generally kaolinized and a little micacized, and with calcite; muscovite (white mica); biotite (black mica), some of it chloritized. Accessory: Magnetite (very little), pyrite, apatite, rutile. Secondary: Calcite, a white mica, chlorite.

An estimate of the mineral percentages by the application of the Rosiwal method to a camera lucida drawing of a thin section, enlarged 25 diameters, yields these results with a mesh of 1 inch and a total linear length of 59 inches, from which, however, areas of mixed particles too fine for measurement and having a total linear length of 18.28 inches had to be deducted, leaving as the total length of measured particles 40.72 inches:

Estimated mineral percentages in "Troy granite."

Quartz		44.94
Potash feldspar (microcline and orthoclase)	31.23	44.29
Soda-lime feldspar (oligoclase-albite)	13.06	
White mica (muscovite)	8.22	10.77
Black mica (biotite)	2.55	
		100.00

The following analysis, made for the Troy White Granite Co., the last operators, by Prof. L. P. Kinnicutt, of the Worcester Polytechnic Institute, in 1891, is given here for reference:

Analysis of "Troy white granite."

Silica (SiO_2)	73.15
Alumina (Al_2O_3)	17.04
Lime (CaO)	.81
Magnesia (MgO)	.30
Potash (K_2O)	5 74
Soda (Na_2O)	2.05
Loss and undetermined	.91
	100.00

Prof. Kinnicutt, by a test made December 11, 1908, found that 100 pounds of this granite absorbs 0.269 pound of water, as compared with 0.371 pound for the same weight of "Concord granite" and 0.420 pound for 100 pounds of quartz monzonite from the New Westerly quarry at Milford, N. H. (p. 188).

The following compression test on a 6-inch cube was made at the United States arsenal at Watertown, Mass., April 15, 1891 (No. 7419): First crack at 525,000 pounds, total 630,100 pounds; ultimate strength per square inch, 17,950 pounds.

This stone is harder than many other granites. It lends itself well to fine carving, as is shown by the garland of roses so finely executed by Joseph Cara-

belli, of New York, on the Hawgood monument at Lake View Cemetery, Cleveland, Ohio.

The quarry, opened about 1859, measured in 1909 about 300 feet in a N. 15° E. direction by 180 feet across and from 50 to 70 feet in depth.

Rock structure: The sheets, 6 inches to 15 feet thick, dip 10°–15° W. There are two sets of joints—(a), strike N. 77° W., dip 65° S. 13° W.; (b), strike about north, one only, on the east wall. The rift is reported as horizontal, and the grain as vertical, with N. 15° E. course. There are biotitic segregations up to 2 inches in diameter. Rusty stain is generally absent, but one sheet surface showed 6 inches of it. An east-west compressive strain is noticeable.

Transportation by an electric siding, 4,230 feet long, operated by a 40-horsepower gasoline engine.

The product is used about equally for buildings and monuments. Specimens: Worcester County Institution for Savings, Worcester, Mass.; Bank of Pittsburg, Pittsburgh, Pa.; Howard Savings Institution, Newark, N. J.; Metropolitan Savings Bank, Baltimore; steps and approaches to Library of Congress, Washington; steps and approaches to New York Library; Hawgood monument and Mark Hanna mausoleum, Lake View Cemetery, Cleveland, Ohio; James Lister monument, Swan Point Cemetery, Providence, R. I.; Albert Wyckoff mausoleum, Woodlawn Cemetery, New York.

COOS COUNTY.

KILKENNY.

The **Kilkenny quarry** is in Kilkenny Township, about 19 miles N. 28° W. from the top of Mount Washington and about 5 miles N. 79° E. from Lancaster station and 940 feet above it, on the southwest side of a ridge. (See Pl. I.) The quarry has been idle for a number of years.

The granite (specimen D, XXX, 73, b), is an augite-biotite granite of dark olive-green color, a little lighter than the green granite of Mount Ascutney, Vt., and considerably darker than the green granite of Redstone, N. H., and Rockport, Mass. (pp. 168, 293). It becomes lighter—that is, more yellowish brown—on continued exposure. The polished face is a dark olive-smoke color. Its texture is even-grained medium, with feldspars up to 0.3 inch and black silicate to 0.1 inch. Its constituents, in descending order of abundance, are medium olive-greenish potash feldspar (orthoclase), intergrown with soda-lime feldspar (probably albite) in alternating bands (microperthite), the feldspar sections almost all nearly rectangular; black (in thin section green) augite; biotite (black mica); greenish hornblende; rare grains of quartz with sheets of cavities; very little separate soda-lime feldspar (probably albite). Accessory: Magnetite, titanite, apatite. Secondary: Limonite from magnetite and biotite following the banding of feldspars. This is conspicuous in long-exposed specimens. No effervescence with muriatic acid test.

The olive tint, as in other green granites, is probably due to the combination of limonite with the originally bluish color of the feldspar. The stone takes a high polish, but some blocks are streaked either from flow structure or from veinlets.

The quarry (the upper and more recent of two openings) is about 50 feet square and 10 feet deep.

Rock structure: The sheets, 1 to 5 feet thick, dip 30° SW. Joints (a), strike N. 45° W., vertical, spaced 6 to 30 feet; (b), strike N. 65° E., vertical or steep southwest, one only on northwest side, slickensided. Minute veins run parallel to joints (b), spaced 6 inches to 3 feet and more, and disfigure that

part of the rock. An aplite dike, 2 inches wide, strikes east. Rusty stain on sheet surfaces is not over an inch thick.

The quarry road to the highway at the foot of the ridge is over half a mile long. There is a disused lumber-railroad bed from the Boston & Maine Railroad at Lancaster, within a mile of the quarry.

Some steps on the south side of the Lancaster House in Lancaster are made of the granite.

STARK.

The **Dawson quarry** is in Stark Township, 3 to 4 miles due east of Groveton station, on a north-south ridge about 800 feet above the station. (See Pl. I.) Operators, Cushing & Frizzell, Groveton. Quarry abandoned.

The granite (specimens D, XXX, 74, a, e), "Stark," is a biotite granite of medium pinkish-gray color (a trifle darker than "Concord granite") and of even-grained medium texture, with feldspars under 0.4 inch and micas to 0.2 inch, exceptionally 0.3 inch. Its constituents, in descending order of abundance, are pinkish potash feldspar (orthoclase), obscurely intergrown with plagioclase (probably oligoclase-albite) and much kaolinized; medium smoky quartz with cavities in sheets, a few in a set at right angles to the others; pinkish soda-lime feldspar (oligoclase-albite); biotite (black mica), some of it chloritized; and rarely a scale of bleached biotite or muscovite. Accessory: Magnetite, allanite, apatite. Secondary: Kaolin, a white mica, limonite, epidote, chlorite. No effervescence with muriatic-acid test.

An estimate of the mineral percentages by the Rosiwal method yields these results with a mesh of 0.3 inch and a total linear length of 66.4 inches: Feldspar, 70.14; quartz, 27.15; mica, 2.71.

This is a constructional granite of dull pinkish color and feeble contrast, which, however, may become stronger as the quarry deepens.

The quarry, opened before 1897, measured in 1909 about 50 by 30 feet and 8 to 20 feet in depth.

Rock structure: The sheets, 6 inches to 3 feet thick, are horizontal. One set of vertical joints strikes N. 80° W. and is spaced 20 feet. There are traces of a north-south set. A few discontinuous ones strike N. 50° E. There are fine-grained light-gray and also black segregations, some of the latter with biotite and quartz inclosed in whitish lenses.

The quarry is operated only in winter, on account of the economy of sledding the stone to Groveton rather than carting it over bad roads.

The product is used for trimmings. Specimens: Trimmings of courthouse, Berlin, N. H., and of several buildings in Lancaster, and a monument in the cemetery at Groveton, N. H.

The firm also opened another quarry in the same stone about a mile north, in Stark. It is near the Grand Trunk Railway and thus has better shipping facilities.

GRAFTON COUNTY.

CANAAN.

The **Mascoma quarry** is on the top of a knoll 1½ miles north-northeast of Enfield station, in Canaan Township. (See Hanover topographic map, U. S. Geol. Survey, also geologic map of Hanover and Lebanon, N. H., by C. H. Hitchcock, Vermont State Geologist Eighth Rept., pl. 46, 1912.) Operator, Norcross Bros. Co., Worcester, Mass. Quarry abandoned.

The granite (specimens D, XXX, 77, a, b, c), "Mascoma," is a biotite granite gneiss of light buff-gray color speckled with black, and of even-grained,

somewhat gneissoid coarse texture, with feldspars up to 0.7 inch and mica aggregates to 0.4 inch. Its constituents, in descending order of abundance, are very light buff-gray (almost cream-colored) potash feldspar (microcline and orthoclase), slightly kaolinized; light smoky quartz, coarsely granulated, with cavities in sheets and cracks parallel thereto; milk-white soda-lime feldspar (oligoclase), much intergrown with quartz minutely circular in cross-section, generally kaolinized and micacized; biotite (black mica), some of it chloritized; and very little muscovite or bleached biotite. Accessory: Magnetite, titanite, apatite, zircon. Secondary: Kaolin, a white mica, chlorite, calcite, rare limonite stain, and probably hematite. It effervesces with muriatic-acid test.

This is a constructional granite, in some respects resembling that of Milford, Mass. (p. 342). It takes a fair polish, and the polished face shows some magnetite. The contrasts are chiefly between the black mica and the other minerals.

The quarry, opened in 1907, measured in 1909 about 147 by 70 feet and 5 to 25 feet in depth.

Rock structure: The sheets, 6 inches to 3 feet thick and over, are about horizontal, forming short lenses. There are three sets of joints: (a), strike N. 50° E., dip 70° N. 40° W., spaced 2 to 25 feet, forms a heading at the northwest corner; (b), strike N. 80° W., dip S. 10° W., spaced 2 to 25 feet; (c), strike N. 65° E., dip 60° N. 25° W., spaced 4 to 8 feet and more. Flow structure strikes north. In the center of the quarry is a flowage band with more pinkish feldspars. The rift is reported as horizontal and the grain as vertical, with N. 32° W. course. A pegmatite dike (smoky quartz and feldspar) up to 5 inches thick strikes northeast. There are lenses or veins of smoky quartz up to 4 inches thick. Biotitic knots measure up to 6 inches across. There is hardly any rusty stain along the surfaces of lower sheets, and on joint faces it is not over 2 inches thick.

Transportation, by cart 2 miles to Enfield station.

The product is used mainly for buildings. Specimens: Tercentennial commemorative monument, Jamestown, Va.; lower stories of Slater Building, Worcester, Mass.; Plain Dealer Building, Cleveland, Ohio; Carnegie Institute, Pittsburgh, Pa.; Royal Bank of Canada, Winnipeg, Manitoba.

LEBANON.

The **Lebanon quarry** is at the east foot of Quarry Hill, on the west side of and close to the Hanover-Lebanon road, 1¼ miles north of Lebanon village, in Lebanon Township. (See Hanover topographic map, U. S. Geol. Survey; also geologic map of Hanover and Lebanon, N. H., by C. H. Hitchcock, Vermont State Geologist Eighth Rept., pl. 46, 1912.) There are some now disused quarries of the same granite higher up on Quarry Hill. Owner, Rockport Granite Co., Rockport, Mass. Quarry idle.

The granite (specimens D, XXX, 76, a, b), "Lebanon pink," is an epidotic biotite granite gneiss of light, faintly pinkish and greenish gray color, speckled with greenish black, and of gneissoid coarse texture, with feldspars up to 0.7 inch and mica aggregates to 0.4 inch. Its constituents, in descending order of abundance, are light-pinkish potash feldspar (microcline and orthoclase, some minutely intergrown with plagioclase), more or less kaolinized; clear colorless quartz, with cavities and few hairlike crystals of rutile, finely granulated; a little greenish soda-lime feldspar (oligoclase-albite to albite), much kaolinized and epidotized; biotite (black mica), usually associated with epidote and some of it chloritized; and a little muscovite (white mica). Accessory: Magnetite, pyrite, titanite. Secondary: Epidote, kaolin, calcite, a white mica,

chlorite. Epidote is fifth in order of abundance. In places the feldspars are surrounded by crushed feldspars and epidote. Effervesces with muriatic-acid test.[80]

This is a constructional granite of mixed greenish and pinkish tint and gneissoid texture, resembling in some respects the granite of Milford, Mass., and also that of the Mascoma quarry. The polish is poor, owing to the presence of large mica aggregates. The polished face shows magnetite and pyrite.

The present quarry was hardly fully opened in 1909. The opening measured then 150 by 50 feet and up to 10 feet in depth.

Rock structure: The sheets, 5 to 10 feet thick, are about horizontal. There are four sets of joints—(a), strike N. 43 W., vertical or steep northeast, also 35° NE., spaced 10 to 20 feet; (b), strike N. 25° E., dip 70° S. 65° E.; (c), strike N. 15° W., dip 55° S. 75° W., spaced 10 feet and more; (d), strike N. 80° E., dip 40° N. 10° W., faced with secondary muscovite, spaced 9 feet and more. The rift is probably horizontal. Dikes of light-pinkish aplite up to 3½ inches thick range from the horizontal to a dip of 30° W. Light and dark segregations are up to 4 inches across. Rusty stain on sheet surfaces is not over 2 inches thick.

Transportation, by cart 1¼ miles to rail at Lebanon.

The product is used for buildings. Specimens of the same granite but largely from now disused openings are the following: India Building, Boston; two stories (polished) of the New York Mutual Life Insurance Building, on Chestnut Street, Philadelphia; two stories of the Borden Building, Hudson Street, New York. The stone has also been used to some extent in the chapel, hospital and Butterfield Memorial buildings of Dartmouth College, at Hanover, N. H.

HAVERHILL.

The **Pond Ledge quarries** are on the southeast side of the domelike granite mass known as Briar Hill, about a mile from Haverhill Center and about 3 miles east of Black Mount station (North Haverhill), in Haverhill Township. (See Pl. I.) Briar Hill lies about N. 60° W. of Black Mountain. Operator (1909), Jessman Granite Co., North Haverhill. Quarries abandoned.

The granite from the southwestern quarry (specimen D, XXX, 75, a), "Pond Ledge gray," is a biotite-muscovite granite of light inclining to medium gray shade, and of even-grained fine texture, but with sparse porphyritic clear feldspars up to 0.4 inch and mica under 0.1 inch. Its constituents, in descending order of abundance, are clear colorless potash feldspar (microcline and orthoclase); clear colorless quartz with cavities and hairlike crystals of rutile and granulated; milk-white soda-lime feldspar (oligoclase-albite), kaolinized, micacized, and with calcite; biotite (black mica), some of it chloritized; muscovite (white mica). Accessory: Magnetite, titanite, apatite, zircon, allanite, rutile. Secondary: Kaolin, a white mica, calcite, epidote, chlorite. Effervesces with muriatic-acid test.

The granite from the northeastern quarry (specimens D, XXX, 75, b, c), "Pond Ledge pink," is a biotite-muscovite granite of light pinkish-gray color and even-grained fine texture, but with sparse porphyritic feldspar up to 0.3 inch and micas to 0.1 inch, rarely 0.2 inch. Its constituents are identical with those of the gray (specimen 75, a), but the secondary minerals include some hematite, which produces the pinkish tint.

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[80] A full microscopic description of this granite was given by J. P. Iddings in U. S. Geol. Survey Bull. 150, p. 353, 1898. He regards the epidote as mostly primary. (See in this connection Butler, B. S., Pyrogenetic epidote: Am. Jour. Sci., 4th ser., vol. 28, pp. 27–32, 1909.)

This stone takes a good polish. It is said to lose some of its pinkish tint on continued exposure.

These "quarries" merely utilize the talus of Briar Hill—that is, material already quarried by glaciers, frost, etc. The blocks are attacked at two points about 1,000 feet apart.

Rock structure: The structure above the talus is not clear. The sheets on top of the hill are said to be horizontal and to range from 6 inches to 10 feet in thickness. On the side above the talus some steep joints or sheets strike nearly with the face of the cliff and are spaced 20 feet and more. There are also gently northwestward-dipping planes, possibly headings. The two granites are reported as merging into each other, the rift as dipping gently northwest, and the "head grain" as forming an angle of 75° to 80° to it. Knots are 2 inches across. Rusty stain is an inch thick on sheets, rarely 6 to 8 inches.

Transportation, by cart 3 miles to rail.

The product is used for monuments at Bath, Lisbon, Haverhill, and Haverhill Center cemeteries.

HILLSBOROUGH COUNTY.

MILFORD DISTRICT.

TOPOGRAPHY.

The Milford quarries lie within a radius of 4 miles northwest, southwest, and south of Milford Village. The region about Milford, as shown on the Milford topographic map published by the United States Geological Survey, is marked by hills and short ridges, from 440 to 760 feet above sea level, trending north or north-northeast. The highest of these hills are Burns Hill (720 feet) and Badger Hill (760 feet), southwest of the village, and Federal Hill (700 feet), southeast of it. This hilly surface is, however, bisected east and west by the valley of Souhegan River, which hereabouts flows between the 206 and 240 foot levels. The locations of the quarries are shown on the map (fig. 38). None of them are above the 400-foot level, or 130 feet above the bench mark at Milford Village.

GEOLOGY OF QUARRIES.

The most interesting geologic features of the Milford granite quarries are the contact phenomena and inclusions. The former have been fully described on page 90 and are illustrated in figure 17 and Plate VIII, *A*. At these places remnants of the gneisses which once probably overlay the granite mass of the entire region are preserved. As these gneisses are evidently themselves granitic rocks which under powerful compression have undergone chemical and textural changes and become schistose, we are led to conclude that the Milford region has been the scene of two intrusions of rock material in molten condition, with an intervening period of metamorphism. The gneiss now capping the granite at the quarries of the Milford Granite Co. (p. 91) represents the earlier granitic rock metamorphosed, the presence of which supplied part of the pressure that made possible as granite the stone now quarried. The strike of the gneiss foliation, N. 75° W., furnishes a clue to the direction from which came the compression that metamorphosed the earlier granite. It is assumed, of course, that these few feet of gneiss are but the shreds of a mass which originally measured hundreds of feet in thickness but which was eroded mainly in preglacial time. The pegmatite dikes, which, apparently starting at the contact, run up into the

gneiss, were probably formed at the time of the intrusion of the underlying granite. This original gneiss of the region is also exposed at the Tonella quarries. (See pp. 186–187.) At two quarries fragments of coarse biotite gneiss occur as inclusions in the granite. (See pp. 64, 187.) These probably formed part of the same overlying gneiss, which, indeed, they closely resemble. This was fractured by the vertical and lateral strain accompanying the intrusion, and

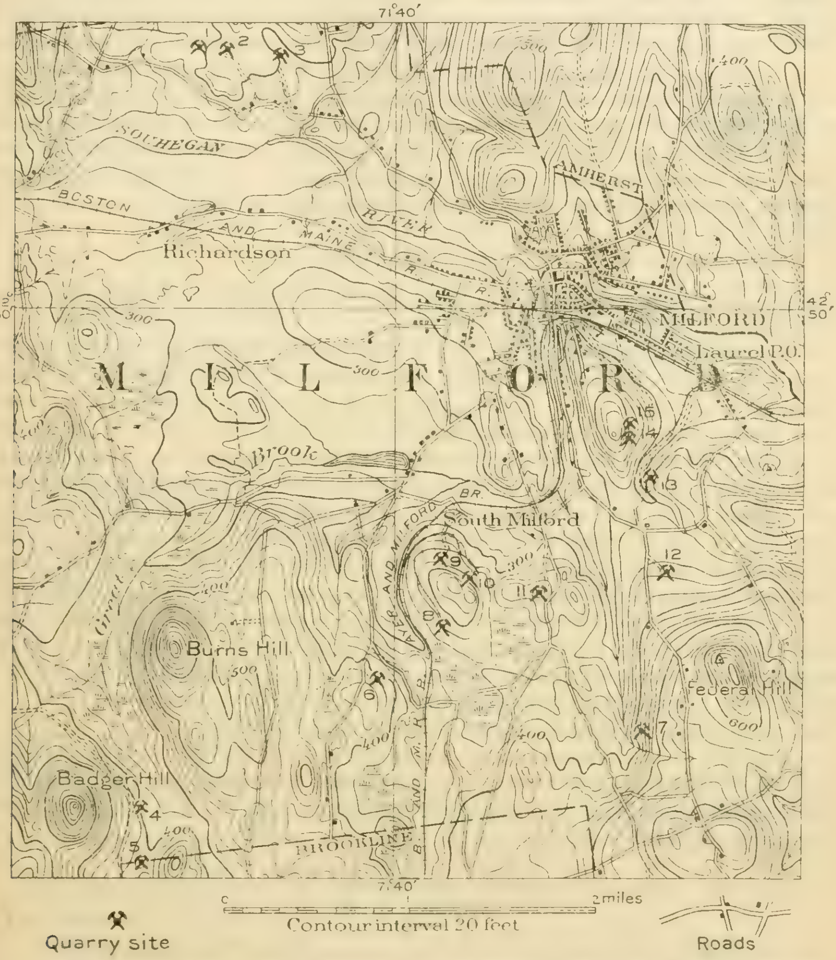

FIGURE 38.—Map of vicinity of Milford, N. H., showing location of granite quarries. 1, New Westerly; 2, Carlton; 3, Bishop; 4, Comolli; 5, Paradise; 6, Tonella; 7, Souhegan; 8, Lovejoy; 9, Pease; 10, Kittredge; 11, Tonella Old; 12, Hayden; 13, Young; 14, Milford Granite Co., south opening; 15, Milford Granite Co., north opening.

fragments fell into the rising semiliquid fused mass. There is also at several quarries a marked banding in the granite, with courses of north, N. 15°, 20°, 50°, 70° E., and N. 75°–80° W., which must have been caused by the granite current (flow structure).

Flow structure about an inclusion at the Daniels quarry has been described on page 64 and the occurrence of pegmatite dikes in groups on page 73. The

courses of pegmatite dikes at the quarries are N. 20°, 25°, 30°, 75° E. and N. 20°, 25°, 50°, 65° W. These must be attributed to a secondary intrusion in the granite in openings possibly due to contraction. The pegmatites thus represent a third access of heated matter to this portion of the crust. Finally, the basic dikes, noted on pages 184, 185, 187, represent a fourth and probably much later injection of rock material in molten condition. The effect, direct or indirect, of these dikes in reddening the adjacent granite is very noticeable (see pp. 185, 187) and appears to be due to the hematitization of the feldspars either by the oxidation of magnetite by water or by the deoxidation of limonite by heat. The most abundant set of joints strikes N. 70°–85° W., its complementary set striking N. 10°–30° E. Others strike north, N. 35°–40°, 45°–50°, 60° E., and N. 30°, 50°, 60° W. The rift is reported at all the quarries as either horizontal or inclined at a very low angle south or S. 70° W. or west. The grain is reported as vertical or dipping 70° N. with a course of N. 60°–90° W., in one place N. 80° E. The sheets are from 3 inches to 30 feet thick.

"MILFORD GRANITE."

The following combines all the more detailed descriptions of specimens and thin sections given on pages 183–190.

The granites of Milford, N. H., are quartz monzonites of light, medium and dark-gray shade, in places of a slight bluish, pinkish, or buff tinge, and always spangled with black mica. The texture of all except one is even grained and very fine to fine, with feldspars and mica in the very fine up to 0.1 inch and in the fine to 0.2 inch. The constituents of these monzonites, in descending order of abundance, are clear to slightly smoky quartz with cavities (in sheets) up to 0.008, 0.017, 0.03 millimeter, and in some quarries with hairlike crystals, probably of rutile; clear colorless to milk-white, bluish, greenish, or pinkish soda-lime feldspar (oligoclase), somewhat kaolinized and micacized; clear colorless to milk-white, bluish, greenish, pinkish, or cream-colored potash feldspar (microcline with or without orthoclase), in places slightly kaolinized and micacized; black mica (biotite), some of it chloritized or bleached. Both feldspars are intergrown with quartz circular in cross section. Accessory: Magnetite, pyrite, apatite, zircon, allanite, and rutile. Secondary: Chlorite, two white micas, carbonate, kaolin, limonite, and hematite.

Estimates of the mineral percentages by the application of the Rosiwal method to camera lucida drawings of three thin sections of the very fine Milford granite from three widely separated quarries (pp. 186, 188, 190) yield the following results:

Average estimates of mineral percentages in monumental granite of Milford, N. H.

Quartz	27.09
Soda-lime feldspar (oligoclase)	34.03
Potash feldspars (microcline 14.15; orthoclase 15.57)	29.72
Black mica	8.58
Magnetite	.25
Minor accessories	.33
	100.00

As the percentages of quartz, soda-lime feldspar, and mica varied considerably in the separate estimates, the averages for these minerals are more trustworthy.

The average diameter of the particles in these three granites, as determined by the same method, is 0.0095 inch, which is about the same as the average of three "blue granites" of Westerly, R. I., given on page 407 as 0.0099 inch.

Messrs. Sullivan, Schaller, and Steiger, chemists, of this Survey, found that granite from five Milford quarries contained from 0.11 to 0.26 per cent of CaO (lime) soluble in hot dilute acetic acid, or an average of 0.16 per cent, which indicates a content of 0.19 to 0.46 per cent, or an average of 0.29 per cent, of $CaCO_3$ (calcium carbonate). The presence of this carbonate is also shown by the microscope and by effervescence with muriatic acid test.

The finer "Milford" granites, which are properly monumental granites, take a high polish, to which the fineness of the mica contributes. The hammered face of these quartz monzonites offers a considerable contrast to the polished face, owing to their large percentage of soda-lime feldspar. The particles are so fine that the only contrast, that between the mica and the other particles, is visible only at a short distance. In the coarser "Milford" granites, in which the mica measures 0.2 inch in two of its diameters, this contrast is more marked. The chief characteristics of all these finer granites are the uniformity and delicacy of their shade or tint, the variety of tints obtainable at the different quarries, and the adaptability of the stone for fine carving. The coarser "Milford" granites are entirely constructional.

QUARRIES.

The **Lovejoy quarry** is in Milford, about 2 miles S. 25° W. of Milford village, on the 380-foot level, on the southwest side of an oblong hill 440 feet high. (See fig. 38.) Operator, Lovejoy Granite Co., Milford.

The granite (specimen D, XXVIII, 51, b), "Milford, N. H.," is a quartz monzonite of light-gray shade spangled with black mica. Its texture is even grained, fine, inclining to medium, with feldspars and mica up to 0.2 inch. It consists, in descending order of abundance, of a milk-white potash feldspar (microcline and orthoclase); in almost equal amount a clear to milk-white soda-lime feldspar (oligoclase), partly kaolinized and micacized; light smoky quartz; biotite (black mica), some of it chloritized. Accessory: Allanite, zircon, apatite. Secondary: Chlorite, two white micas, kaolin, carbonate, and hematite.

George Steiger finds that this granite contains 0.14 per cent of CaO (lime) soluble in hot dilute acetic acid, which indicates the content of 0.25 per cent of $CaCO_3$ (calcium carbonate); the microscope also shows the presence of a carbonate. Effervesces slightly with muriatic-acid test.

The quarry, opened about 1886, measured in 1906 477 feet N. 35° E. by 150 feet across and from 5 to 20 feet in depth.

Rock structure: The sheets, from 3 inches to 10 feet thick, but mostly up to 5 feet 6 inches, dip 5°–10° E. or SE. There is but one set of joints, vertical, strike N. 85° W., recurs at intervals of 40, 100, and 330 feet, and forms a 4 to 10 foot heading 140 feet from the north end. The rift is reported as horizontal but tending to incline with the sheets, the grain as vertical with east to west course. In summer the rock splits without reference to rift and grain. A flow structure, shown by more micaceous bands alternating with some 2-inch white bands, strikes N. 40° W. and dips 25° NE. Pegmatite dikes, up to 2 inches thick, strike N. 65° W., exceptionally N. 25° E. They consist of half-inch particles of clear to milky striated soda-lime feldspar (oligoclase), light smoky quartz, and black mica with magnetite and pyrite. There are no knots. Rusty stain is light and up to 6 and 18 inches thick, but is not present on all sheets.

Transportation, as shown on the map (fig. 38), by siding from the Boston & Maine Railroad.

Specimen structures: Pier 4 of Haverhill Bridge, Essex County, Mass.; piers 4 and 6 of the railroad bridge at the same place; trimmings of Majestic Theater, Chicago; and Ferguson mausoleum at Kensico Cemetery, New York.

The **Kittredge quarry** is in Milford, about 1½ miles S. 15° W. of Milford village, on the 360-foot level of the same hill as the Lovejoy quarry but on the opposite side. (See fig. 38.) Operator, Edward L. Kittredge, Milford.

The granite (specimen D, XXVIII, 50, b) is a quartz monzonite of light-gray shade, with very slight bluish tinge apparent when the stone is in large masses, spangled with black mica. Its texture is even grained, fine, inclining to medium, with feldspars up to 0.2 and mica to 0.1 inch. In four thin sections the particles do not exceed 2.96 millimeters, or 0.012 inch, and most of them are not 2.2 milimeters, or 0.08 inch. At very rare intervals porphyritic feldspars occur up to 1½ inches in diameter. Its constituents, in descending order of abundance, are very slightly bluish milk-white potash feldspar (microcline intergrown with quartz, and orthoclase); in almost if not quite equal amount clear colorless to milk-white soda-lime feldspar (oligoclase), partly micacized and kaolinized; light smoky quartz with sheets of cavities and rift or grain cracks parallel to them; and biotite (black mica), some of it chloritized. Accessory: Magnetite, allanite, zircon, and apatite. Secondary: Kaolin, chlorite, white mica, and limonite. In the upper sheets the stone is of light cream color owing to limonite proceeding from magnetite and allanite particles.

This is a constructional granite closely resembling that of the Lovejoy quarry, on the other side of the hill, but with slightly finer mica scales and a more bluish tinge. It effervesces very slightly with muriatic-acid test.

A very fine monumental granite (specimen D, XXVIII, 50, a), forming a band 20 feet wide at the south end of the quarry, is also a quartz monzonite of light-gray shade with very slight bluish tinge and spangled with fine black mica. Its texture is very fine, with feldspars measuring up to 1.85 millimeters and the mica 0.74 millimeter. The constituents are like those of the coarser stone, but the potash feldspars appear to predominate.

The quarry, opened about 1890, measured in 1906 800 feet from north to south by 200 feet across and from 5 to 40 feet in depth. The working face is on the southwest.

Rock structure: The sheets are lenticular, from 4 inches to 2 feet 10 inches thick, and dip at a low angle north and east. There are three sets of joints—(a), strike N. 22° E., vertical, forms a heading 5 to 7 feet wide on each side of a basic dike; (b), strike N. 70° W., vertical, spaced 200 feet; (c), strike N. 45° E., dip 55° N. 45° W., exceptional. The rift is reported as horizontal, and the grain as vertical with a N. 80° E. course. A flow structure marked by parallel bands of black mica strikes N. 20° E., also N. 50° E., with a dip of 20° NNW. and NW. A basic dike, a foot thick, striking N. 22° E. and vertical, forms the east wall. This is related to joint system (a). Pegmatite dikes, 1½ to 3 inches thick, strike N. 20° and 50° W., forming in one place a network with meshes 15 feet square.

Transportation, by siding from Boston & Maine Railroad (fig. 38). Seven-eighths of the product consisted of paving, curbing, flagging, and crossings; the rest is dimension stone and bases for monuments.

The **Pease quarry** is in South Milford, about 1½ miles S. 25° W. of Milford village, on the 350-foot level, on the same hill as the Lovejoy and Kittredge quarries. (See fig. 38.) Operator, Pease Co., Nashua.

The granite in the east half of the quarry is a quartz monzonite of light-gray shade with very slight bluish tinge apparent only in large masses of the

stone, and spangled with black mica. Its texture is fine inclining to medium, with feldspar and mica up to 0.2 inch. Its constituents are identical with those of specimen 50, b, from the Kittredge quarry (p. 184).

The granite from the west half of the quarry (specimen D, XXVIII, 64, a) is a quartz monzonite of light buff-gray color spangled with black mica. Its texture is even grained, fine inclining to medium, with feldspar and mica up to 0.2 inch. Its constituents, in descending order of abundance, are light smoky quartz with cavities in sheets, many parallel; clear colorless to milk-white soda-lime feldspar (oligoclase); light buff-gray potash feldspar (microcline); both feldspars somewhat kaolinized and micacized; and biotite (black mica), some of it chloritized. Accessory: Magnetite, apatite, and zircon. Secondary: Kaolin, white micas, chlorite, and carbonate. It effervesces slightly with muriatic-acid test.

This is a constructional granite of warm tint with conspicuous small black micas.

The quarry, opened in 1886, measured in 1906 about 600 feet east-west by 400 and 300 feet from north to south, and from 35 to 60 feet in depth.

Rock structure: The sheets are lenticular, from 2 to 22 feet thick, and have a slight northerly dip. There are two sets of joints—(a) strike N. 15° E., vertical, spaced 50 to 200 feet, forms headings on west wall and 200 feet east of it next to the dikes; (b) strike N. 80° W., dip 75° S., spaced 5 to 50 feet, occurs on north and south walls. The rift is reported as horizontal, and the grain as vertical with N. 65° W. course. A flow structure, shown by biotitic bands, alternating with more feldspathic and quartzose ones, strikes N. 70°–75° W. and dips 25° S. This is conspicuous on the south side, but at the southwest corner, where the granite is overlain by a gneiss, as shown in fig. 17 (p. 191), the flow structure has a N. 70°–75° E. course and dips 20°–25° S. The strike of the gneiss is N. 75° W. and the dip 20° S. This gneiss consists of light-gray to milk-white soda-lime feldspar (oligoclase), smoky quartz, biotite, with magnetite, apatite, and zircon. It is thus a mica diorite gneiss. There are two basic dikes striking N. 15° E. and vertical; one, 4 feet thick, makes the west wall; the other, 12 to 18 inches thick, forms a jog 200 feet east of it. Within 50 feet of the thicker dike the granite passes from a light buff gray to a medium pinkish-gray, "Milford pink," owing to the darkening of the feldspars and to hematitic stain. These dikes are also the probable cause of the difference between the color of the granite in the western and eastern halves of the quarry, the amount of hematitic stain increasing with the nearness of the dikes. (See pp. 184–185.) A 4-inch pegmatite dike strikes N. 65° W. and consists of quartz, white feldspar, and biotite, the particles being up to 2 inches in diameter. Rusty stain up to 2 inches thick occurs on some sheets only.

Transportation, by siding from Boston & Maine Railroad.

The product is used for bridges and buildings and the waste for paving. Specimen building of "pink stock"; Thayer Memorial Library, Franklin, Mass.; railroad bridge, Neponset, Mass.; and Piers 12, 25, 26, and 32 on the Prison Point Street Bridge (Boston & Maine Railroad), East Cambridge, Mass.; and east side coping of Atlantic Avenue Bridge, Boston.

The **Tonella old quarry** is in Milford, 1½ miles south of Milford village. (See fig. 38.) Quarry no longer operated.)

The granite (specimens D, XXVIII, 54, a, b) is a quartz monzonite of light-gray shade (without either bluish or greenish tinge), with very minute black spangles. Its texture is fine, even grained, with feldspars up to 0.15 inch, and black mica in slender scales but exceptionally over 0.1 inch. Its constituents, in descending order of abundance, are very light smoky quartz with hairlike crystals, probably of rutile, and cavities in sheets; clear colorless to

milk-white soda-lime feldspar (oligoclase) slightly kaolinized and micacized; very light gray potash feldspar (microcline and orthoclase), mostly intergrown with quartz, circular in cross section, and some of it very slightly kaolinized; and biotite (black mica), some of it chloritized. Accessory: Magnetite, zircon, allanite, apatite, and rutile. No pyrite detected. Secondary: Kaolin, chlorite, and two white micas.

An estimate of the mineral percentages, made by applying the Rosiwal method to a camera lucida drawing of a thin section enlarged 40 diameters, yields the following results with a mesh of 1.7 inches and a total linear length of 42 inches: Quartz, 36.76; soda-lime feldspar (oligoclase), 29.16; potash feldspars (microcline 14.00, orthoclase 13.58), 27.58; black mica, 6.50. The average diameter of the particles obtined by the same method is 0.011 inch.

This is a fine-grained monumental granite, in shade a trifle lighter than the granite of Hallowell, Maine, but not as light as that of North Jay, Maine. It takes a high polish. The only contrast, visible but a few feet off, is between the black mica and the combined quartz and feldspars. The polished face shows many minute particles of magnetite.

The quarry, opened in 1900, measured in 1906 about 300 feet north and south by 100 feet across and is now 75 feet deep.

Rock structure: The sheets, 2 to 14 feet thick, are lenticular, horizontal, and regular. There are two sets of joints—(a), strike N. 85° W., vertical or steep south, spaced 20 to 50 feet, forms a heading 3 feet wide, 125 feet from the south end; (b), strike N. 35–40° E., vertical, intermittent and confined to upper sheets, forms a heading on the east wall, and recurs 30 feet from west wall. From the large blocks of gneiss attached to granite lying on the dumps and from the occurrence of this gneiss in a much weathered condition in or under the drift on the edge of the quarry it is evident that the rock surface originally included a mass of gneiss which either capped the granite or formed a large inclusion in its upper part. This gneiss is coarse, biotitic, with lenses of pinkish potash feldspar (microcline) bordered with clear to milk-white soda-lime feldspar (oligoclase). Its quartz is smoky. Accessory: Pyrite, magnetite, allanite, and zircon. The rift is reported as horizontal and the grain as vertical, with N. 85° W. course. There are no dikes, veins, or knots. Rusty stain occurs only along the headings, where it is 6 inches thick. This quarry is remarkably free from the common structural difficulties.

Transportation, by cart, half a mile to railroad for rough stock, but 2 miles to cutting shed for blocks to be finished.

The product was used principally for monuments, and the waste for paving. The firm made a specialty of fine carved work. Specimens: the Morgenthaler monument, Greenwood Cemetery, Hamilton, Ohio. This is a 5-ton block, 6 feet high, with a delicately carved branching ivy vine entwined about a cross, all in high relief on a roughly chipped face. The carving, having been done with hand instead of pneumatic tools, is sharp.

The **Tonella King quarry** is 2¼ miles S. 25° W. of Milford village. (See fig. 38.) Operators, Tonella & Sons, Milford.

The granite (specimen D, XXVIII, 55, a) is a quartz monzonite of medium buff-gray color spangled with fine black mica. Its texture is generally even-grained and fine, with feldspar up to 0.2 inch and mica to 0.1 inch, but with rare porphyritic light-pinkish feldspars an inch in diameter. Its constituents, in descending order of abundance, are light amethystine to pale smoky quartz; clear colorless to milk-white soda-lime feldspar (oligoclase), partly kaolinized and micacized; light-buff to cream-colored potash feldspar (microcline, much intergrown with quartz, circular in cross section); and black mica, some of it chloritized. Accessory: Magnetite, allanite, apatite, and zircon.

Secondary: Kaolin, a white mica, chlorite, hematite from magnetite, and limonite from allanite.

In general color this rock resembles specimen 64, a, of the Pease quarry (p. 184), but its mica scales are finer.

A finer granite (specimen D, XXVIII, 55, c) from the upper part of the quarry is also a quartz monzonite of medium buff-gray color, spangled with extremely fine mica. Its texture is even grained, very fine, with feldspars up to 0.1 inch and mica rarely over 0.05 inch. Its constituents are the same as those of the other.

A pinkish granite (specimen D, XXVIII, 55, d) 8 feet thick, on the south side of the dike described beyond, is of pinkish medium-gray color, like that adjoining the dike in the Pease quarry (p. 185). It is the same granite as 55, a, described above, but its oligoclase contains hematite, and its potash feldspars are also pinkish, owing to the dike.

The quarry, opened in 1905, measured. in 1906, 100 feet north and south by 80 feet across, and is now 75 feet deep.

Rock structure: The sheets, 18 inches to 6 feet thick, are lenticular and horizontal or dip as high as 20° E. Only one set of joints, strike N. 30° W., dip 35° W., spaced 5 to 20 feet. The granite is capped on the east and west sides by about 5 feet of coarse biotite gneiss, but on the west this is overlapped by 2 to 3 feet of granite, and so the gneiss may be merely a large inclusion. This gneiss (specimen D, XXVIII, 55, b) consists of pinkish potash feldspar (microcline) and milk-white soda-lime feldspar, both intergrown with quartz; smoky quartz with cavities in sheets; and biotite. The foliation of the gneiss strikes about N. 45° W. The rift is reported as horizontal, and the grain as vertical, with N. 80° W. course. A flow structure shown by more biotitic streaks and planes strikes north and dips 20° W. The band of fine-grained granite, 2 feet thick at the top (specimen 55, c), lies in the flow direction. On the south side a vertical dike of augite camptonite 2 feet 6 inches thick strikes N. 10° E. This consists of soda-lime feldspar (andesine), augite, brown hornblende, magnetite in octahedra and skeleton crystals, apatite in slender prisms all through the feldspar, and pyrite, together with secondary chlorite and carbonate from alteration of augite. Specimens of product: Hudson Monument, Lakewood Cemetery, Minneapolis, Minn., and Gareiss Monument, Chicago.

The **Souhegan quarry** is 2½ miles S. 12° E. from Milford village and three-fifths of a mile southwest of Federal Hill. (See fig. 38.) Operator, Smalley-Souhegan Granite Co., Milford.

The granite (specimens D, XXVIII, 53, a, b, c) is a quartz monzonite of dark-gray shade with very slight pinkish tinge and very fine scales of black mica. Its texture is even grained and fine, with feldspar and mica not over 0.1 inch. Its constituents, in descending order of abundance, are light smoky quartz with few cavities, some in sheets; milk-white soda-lime feldspar (oligoclase), slightly kaolinized and micacized; colorless to dull greenish-gray potash feldspar (microcline), intergrown with quartz, circular in cross section; and biotite (black mica), some of it chloritized. Accessory: Magnetite, pyrite, apatite, allanite, and zircon. Secondary: Kaolin, a white mica, chlorite, carbonate, and some irregularly disseminated hematite stain which gives the pinkish hue.

George Steiger, of this Survey, finds that this granite contains 0.26 per cent of CaO (lime) soluble in hot dilute acetic acid, which indicates a content of 0.46 per cent of $CaCO_3$ (calcium carbonate); the presence of this carbonate is also shown by the microscope and by muriatic-acid test.

The stone takes a high polish and offers a notable contrast of shade between its hammered and polished faces. The polished surface shows rare

particles of pyrite along with the usual abundance of magnetite particles. The only contrast between its minerals, that between the black mica and the general color of quartz and feldspar, is visible but a few feet off.

The quarry, opened in 1896, measured in 1906, 150 by 50 feet and 10 to 25 feet in depth.

Rock structure: The sheets, generally normal and from 6 inches to 5 feet thick, dip low west and south, but are intersected by sharply curved planes, "toe nails." There are two sets of joints—(a), strike N. 80° W., vertical, occurs only in the southern part; (b), strike N. 22° E., vertical, forms headings on the east and west walls and recurs discontinuously at intervals of 10 feet. There is a rhomb-shaped inclusion at the south end, about 3 feet 6 inches across, of very coarse biotite gneiss, consisting of milk-white soda-lime feldspar (oligoclase-andesine), smoky quartz, and biotite, with a little copper pyrite. There is some banding in the granite parallel to the surface of the inclusion. (See p. 64.) The rift is reported as in places horizontal but generally dipping south at a very low angle, and the grain as vertical with N. 70° W. course. A pegmatite dike, up to 2 inches thick, with a little magnetite, strikes N. 30° E Rusty stain on the sheet surfaces is up to 6 inches thick.

Transportation, by cart 3 miles to cutting shed on siding of Boston & Maine Railroad.

The product is used for monuments.

The **New Westerly quarry** is 2¼ miles northwest of Milford village. (See fig. 38.) Operator, New Westerly Granite Co., Milford.

The granite (specimens D, XXVIII, 60, a, b), "New Westerly blue," is a quartz monzonite of medium slightly bluish-gray color, spangled with fine black mica. Its texture is even-grained, fine, inclining to medium, with feldspar and mica up to 0.2 inch and a marked parallelism in the mica scales. Its constituents, in descending order of abundance, are light smoky quartz with cavities up to 0.008 millimeter in sheets; slightly greenish-blue soda-lime feldspar (oligoclase), partly kaolinized and micacized; slightly pinkish-gray potash feldspar (microcline, some twinned); biotite, (black mica), some of it chloritized. Both feldspars are intergrown with quartz. Accessory: Magnetite, pyrite, allanite, apatite, and zircon. Secondary: Kaolin, two white micas, chlorite, hematite, and carbonate.

An estimate of the mineral percentages, obtained by applying the Rosiwal method to a camera lucida drawing of part of a thin section, enlarged 40 diameters, yields the following results with a mesh of 1.5 inches and a total linear length of 34.5 inches: Quartz, 17.10; soda-lime feldspar (oligoclase), 45.22; potash feldspars (microcline 15.59; orthoclase 15.71), 31.30; black mica (biotite), 5.74; magnetite, 0.64. The average diameter of all the particles, obtained by the same method is 0.009 inch.

George Steiger, chemist, of this Survey, finds that this granite contains 0.12 per cent of CaO (lime) soluble in hot dilute acetic acid, which indicates a content of 0.21 per cent of $CaCO_3$ (calcium carbonate); the presence of this carbonate is shown by the microscope and by muriatic acid test.

The stone takes a high polish, which brings out the greenish and reddish tints and darkens the general color so that it becomes a medium greenish gray. The polished face shows a few grains of magnetite and rare ones of pyrite.

The quarry, opened in 1876, measured in 1906 about 150 feet from east to west by 100 feet across and from 15 to 65 feet in depth.

Rock structure: The sheets, 6 inches to 30 feet thick, increasing in thickness downward, dip south at a low angle. There are two sets of joints—(a), strike N. 10° E., dip 60° E. and 90°, spaced 3 to 50 feet, forms a heading on east side; (b), strike N. 75°–80° W., vertical, spaced 30 to 40 feet, forms a heading on

the south side. The rift is reported as horizontal, and the grain as vertical with a N. 80° W. course, but it is so feeble that the stone can be split almost as well across it.

Transportation, by cart about 2¾ miles to cutting shed and railroad at Milford.

The product is used for monuments.

The **Milford Granite Co.'s quarries** are a mile southeast of Milford village and 130 feet above it, on the east side of a hill. (See fig. 38.) The quarries are abandoned.

The granite generally is like that of the Young quarry, described on page 190.

The quarries comprise two openings, along a N. 20° E. line. The southern opening is about 120 feet N. 20° E. by 60 feet across and is 40 feet deep. The northern opening, separated from the other by an interval of 150 feet, is about 900 feet N. 20° E. by 50 to 75 feet across and from 10 to 30 feet deep.

Rock structure: The sheets, 1 to 5 feet thick, are lenticular and horizontal. Joints, strike N. 10°–30° E., vertical, spaced 1 to 5 feet, form headings on the east and west walls of both quarries and in center of southern one. Some of the joints of these headings are "sand seams," or veins up to half an inch thick of a central band of quartz crystals with borders of muscovite. (See p. 74.) The granite of the west wall of both quarries is overlain by a mass of many-colored banded gneiss, 12 to 16 feet thick, with a foliation striking about N. 75° W. and dipping 75° S. with injections of pegmatite starting at the contact and tapering out within the gneiss. (See Pl. VIII, *A*, and p. 91.) There is much variety in the composition and texture of the gneiss. The quartz of the finer augite diorite gneiss has cavities, up to 0.047 millimeter, in sheets intersecting at right angles. The granite on either side of the muscovite veins in the heading is much reddened for half an inch; the biotite is mostly chloritized, the oligoclase is much kaolinized and micacized, and much limonite and hematite stain proceeds from particles of magnetite and pyrite.

The **Carlton quarry** is 2 miles northwest of Milford village. (See fig. 38.) Operator, C. V. Carlton, Milford. Idle since 1913.

The granite (specimen D, XXVIII, 61, a) appears to be also a quartz monzonite, but probably with more of the potash feldspar. Its color is medium pinkish gray, spangled with black. Its texture is porphyritic; the groundmass is fine, with feldspar and mica up to 0.1 inch and the isolated feldspars up to 0.4 and exceptionally 1 inch. Its constituents, in descending order of abundance, are light smoky quartz with hairlike crystals, probably of rutile, and cavities in sheets, with rift cracks parallel to them; light pinkish-gray potash feldspar (microcline), intergrown with quartz, circular in cross section, inclosing particles of soda-lime feldspar, and somewhat kaolinized and micacized, making up part of the groundmass and also the porphyritic crystals; in almost equal amount a milk-white soda-lime feldspar (oligoclase), somewhat kaolinized, micacized, and intergrown with quartz; and biotite (black mica), some of it chloritized. Accessory: Magnetite, apatite, allanite, and rutile. Secondary: Kaolin, two white micas, chlorite, and hematite.

At the north corner of the quarry there is a band of quartz monzonite of medium slightly bluish-gray color, with fine black mica, like the stone of the New Westerly quarry described on page 188.

The chief product of this quarry differs from all the other granites of Milford, N. H., by its marked porphyritic texture. It is a constructional granite.

The quarry, opened in 1881, was in 1906 about 110 by 100 feet and averaged 30 feet in depth.

Rock structure: The sheets, 1 to 16 feet thick, dip west at a low angle. There are two sets of joints—(a), strike N. 50° W., about vertical, spaced 20 to 60

feet, forms a heading on the west side and the east wall; (b), diagonal, strike north, dip 75° E., one joint only. The rift is reported as slightly inclined to the west. and the grain as dipping 70° N. Flow structure, shown by streaks of black mica, also by the band of fine granite, strikes N. 70° E. and dips 40°–50° N. 20° W. Rusty stain is up to 8 inches thick.

Transportation, by cart, 2 miles to Milford.

The product is used mostly for street work in Boston and Cambridge.

The **Young quarry** is 1¼ miles southeast of Milford village and three-fourths mile southwest of East Milford, or Laurel post office. (See fig. 38.) Operators, Young's Sons & Co., Milford.

The granite (specimens D, XXVIII, 52, aa, c), "dark-blue New Westerly," is a quartz monzonite of general dark-gray shade (neither bluish, greenish, nor pinkish but smoky), with very fine black spangles. Its texture is even-grained and fine, with feldspar up to 0.1, rarely 0.15 inch, and mica to 0.1 inch. Its constituents, in descending order of abundance, are very light smoky quartz, with cavities; slightly greenish-gray soda-lime feldspar (oligoclase), somewhat kaolinized and micacized; clear, colorless to grayish potash feldspar (microcline and orthoclase), very slightly kaolinized; and black mica, some of it chloritized. Accessory: Magnetite, pyrite, apatite, allanite, and zircon. Secondary: White mica, kaolin, chlorite, carbonate, and a little hematite and limonite stain, the latter about the allanite.

An estimate of the mineral percentages obtained by applying the Rosiwal method to a camera lucida drawing of part of a thin section enlarged 40 diameters yields these results with a mesh of 2 inches and a total linear length of 34 inches:

Estimated mineral percentages in granite from the Young quarry, Milford, N. H.

Quartz	27.40
Soda-lime feldspar (oligoclase)	27.70
Potash feldspars (microcline 12.87, orthoclase 17.41)	29.28
Black mica (biotite)	13.51
Magnetite	.11
Allanite	1.00
(Accessory, 1.11.)	
	100.00

The percentages of magnetite and allanite are not perfectly reliable, for a slight shifting of the mesh would have changed the figures for one or both, but as representing together the accessories they are not far from the truth. The average diameter of all the particles, by the same method, is 0.0084 inch.

W. T. Schaller, a chemist of this Survey, finds that this granite contains 0.18 per cent of CaO (lime) soluble in hot dilute acetic acid, which indicates a content of 0.32 per cent of $CaCO_3$ (calcium carbonate); the presence of this carbonate is also shown by the microscope and by muriatic-acid test.

A crushing test, made for the firm by Prof. Ricketts, of the Rensselaer Polytechnic Institute, at Troy, N. Y., is reported as showing an ultimate crushing strength of 24,950 pounds to the square inch.

The stone takes a fine polish. The polished face shows some magnetite and a little pyrite. There is much contrast of shade between the hammered and the rough or polished face, the hammered face being light, slightly bluish gray. The contrast between the minerals, not visible at a distance, is between the black mica and the general color of the others.

The quarry, opened in 1886, a plan of which is shown in figure 39, had in 1906 a length of 370 feet, a width of 75 to 100 feet, and an average depth of 50 feet. Only the northwest bend was being worked in 1906.

Rock structure: The sheets, 2 to 10 feet thick, are lenticular and generally horizontal. Joint courses are given in figure 39. (A), vertical, forms a heading at the west end, and recurs 70 feet east only; (B), dip 40° N., spaced 5 to 10 feet, and occurs only at the northwest corner. The rift is reported as horizontal, but with a slight inclination. There is no perceptible grain. Flow structure, shown by biotitic streaks, strikes N. 15° E. and dips 45° W. The marked feature of this quarry is the recurrence, at intervals of 20 feet, of dikes of pegmatite and aplite, already described on page 73. These dikes are from 0.25 to 3 inches thick, occur in sets of three to eight, with a N. 25° W. course and a vertical dip. A few strike N. 25° E. and dip 40° ESE. They consist of cream-colored oligoclase, smoky quartz, cream-colored or pink microcline, and biotite, with magnetite, allanite, and zircon. The biotite crystals measure up to 2 inches in length. Rusty stain is up to 8 inches wide on sheet surfaces. Joints A are coated with pyrite, which has mostly passed into limonite.

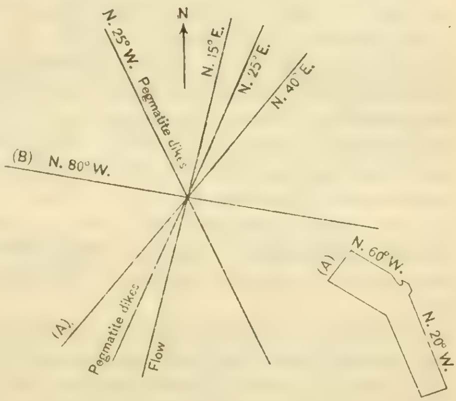

FIGURE 39.—Structure and plan of Young quarry, Milford, N. H.

Transportation, by cart three-fourths mile to cutting shed, on the Boston & Maine Railroad, with siding to quarry.

The product is used for monuments, the stained and veined parts and small sheets for paving. Specimens: Mrs. R. J. Stark monument, Oakwood Cemetery, Troy, N. Y.; Mrs. J. Craig monument, Rural Cemetery, Albany, N. Y.

BROOKLINE.

The **O'Rourke quarry** is at the east end of Brookline village, in Brookline Township. (See topographic map of Groton quadrangle, U. S. Geol. Survey.) Operator, O'Rourke & Magner Quarrying Co., Brookline, N. H., also 73 North Street, Salem, Mass. Quarry abandoned.

The granite (specimen D, XXX, 87 a), "Brookline," is a quartz monzonite of medium buff-gray color and of even-grained fine texture, with feldspars and micas under 0.2 inch. Its constituents, in descending order of abundance, are light smoky quartz with cavities; cream-colored soda-lime feldspar (oligoclase), kaolinized and micacized; clear to translucent whitish potash feldspar (microcline and orthoclase), intergrown with quartz, circular in cross section; biotite (black mica), some of it chloritized; and a little muscovite or bleached biotite. Accessory: Magnetite, apatite, zircon. Secondary: Kaolin, a white mica, calcite, chlorite. No effervescence with muriatic-acid test.

This is a fine-grained monumental granite closely related to that of Milford, in the same county. It cuts light.

The quarry, opened in 1909, is on a bare ledge measuring 200 feet in a N. 20° E. direction by 100 feet across.

Rock structure: The sheets, 1 to 8 feet thick, dip mostly east at low angles. There are two sets of joints—(a), strike N. 20° E., vertical, spaced 6 to 12 feet, forms a small heading on the west side; (b), strike N. 80° W., vertical, spaced 25 feet and more. The rift is reported as horizontal, and the grain as vertical. Inclusions of gneiss up to 6 by 3 feet occur. (See p. 63.) Rusty stain is 2 inches thick on surface sheets, but very little on the lower ones.

Transportation, by cart three-fourths of a mile to the railroad.

The product is used for monuments and trimmings. Specimens: Simon Cottan and Philip Sheridan monuments, St. Mary's Cemetery, Salem, Mass. The quarry was not operated in 1916.

The **Fessenden quarry** is one-eighth of a mile west of South Brookline station, in Brookline Township. (See Groton topographic map, U. S. Geol. Survey.) Operator, John R. Richards, Brookline.

The granite (specimens D, XXX, 88, a, b), "Brookline," is a quartz monzonite of medium, faintly pinkish-gray color and of even-grained fine texture, with feldspars up to 0.15 inch and micas to 0.1 inch. Its constituents, in descending order of abundance, are very light smoky quartz with cavities and hairlike crystals of rutile; milk-white soda-lime feldspar (oligoclase), kaolinized and micacized; slightly pinkish potash feldspar (microcline and presumably orthoclase); biotite (black mica), some of it chloritized; and a little muscovite or bleached biotite. Accessory: Magnetite, apatite, zircon, allanite. Secondary: Kaolin, white micas (one in veinlets), hematite and limonite stain, chlorite, calcite. Very slight effervescence with muriatic-acid test.

An estimate of the mineral percentages, made by applying the Rosiwal method to a camera lucida drawing of a thin section enlarged 40 diameters, yields these results with a mesh of 2 inches and a total linear length of 48 inches:

Estimated mineral percentages in "Brookline" quartz monzonite from Fessenden quarry.

Soda-lime feldspar (oligoclase)	38.79	61.71
Potash feldspar (microcline and orthoclase)	22.92	
Quartz		32.20
Black mica (biotite)	5.08	5.24
White mica (muscovite) or bleached biotite	.16	
Magnetite		.85
		100.00

The average diameter of the particles calculated from the same measurements proves to be 0.0097 inch.

This is a fine-grained monumental granite, related to that of Milford, in the same county. Its color is warmer than that of the rock from the O'Rourke quarry, but the granites are the same. It takes a high polish and like other quartz monzonites cuts light.

The quarry, opened in 1909, was about 80 by 50 feet and up to 8 feet deep.

Rock structure: The sheets, 2 to 3 feet thick, range from the horizontal to a gentle easterly dip. There are two sets of joints—(a) strike N. 30° E., vertical, one only in center; (b), strike N. 75° W., vertical or steep, spaced 10 to 20 feet. The rift is reported as horizontal, and the grain as vertical, with N. 20° E. course. There are inclusions of coarse gneiss and granite up to 21 inches in diameter. (See p. 63.) Rusty stain on top sheets is not over 2 inches thick.

Transportation, by cart one-eighth mile to railroad.

The product is used for monuments and has been shipped to Pepperell and Claremont, N. H.; Quincy, Mass.; Ohio; and Pennsylvania.

NASHUA.

The **Stevens quarry** is near West Hollis Street, in Nashua, 2¼ miles west-southwest of the confluence of Nashua and Merrimac rivers. (See Manchester topographic map, U. S. Geol. Survey.) Operator, Nashua Granite Co., 254 Main Street, Nashua. Idle in 1921.

The granite (specimen D, XXX, 86, a) is a muscovite-biotite granite gneiss of light-gray shade and of gneissose medium texture, with feldspar under 0.4 inch (rarely 0.7 inch) and micas under 0.2 inch. The rift is at right angles to the foliation. Its constituents, in descending order of abundance, are milky potash feldspar (microcline, some of it kaolinized, and orthoclase); light smoky quartz, with hairlike crystals of rutile and granulated (particles 0.05 to 0.25 millimeter across); milk-white soda-lime feldspar (albite to oligoclase-albite), much kaolinized and somewhat micacized; muscovite (white mica) in plates and stringers, which with the granulated quartz surrounds the larger feldspars; biotite (black mica), a little of it chloritized. Accessory: Garnet, apatite, rutile. Secondary: Kaolin, white micas, chlorite. No effervescence with muriatic-acid test.

The quarry, opened about 1840, measured in 1909 about 175 feet in a northeasterly direction by 125 feet across and from 10 to 20 feet in depth.

Rock structure: The sheets, 6 inches to 6 feet thick, dip 10° SE. There are two sets of joints—(a) strike northeast, vertical, spaced 5 to 20 feet, forms a heading on the northwest wall, one 15 feet from the southeast wall, and a discontinuous one on the northeast wall; (b) strike N. 60° W., vertical, less abundant, and at irregular intervals. The foliation strikes N. 67° E., dips 90°, and has micaceous faces. The rift is horizontal, the grain is parallel to the foliation, and the hard way is vertical with northwest strike. A pegmatite dike up to a foot thick, on the northeast side, strikes northeast. A pegmatite lens, 30 by 3 to 4 feet, has the same strike.

Transportation, by siding from Boston & Maine Railroad.

The product is used for trimmings and curbing, for which its foliation and marked rift well adapt it.

MERRIMACK COUNTY.

ALLENSTOWN.

The **Bailey quarry** is in Allenstown, 2 miles about north-northeast of Suncook station. Operator, Charles A. Bailey, Suncook.

The granite (specimens D, XXX, 81, a, b), "Allenstown," is a muscovite-biotite granite of light-gray shade and of even-grained medium texture, with feldspars up to 0.3 inch and mica to 0.2 inch, rarely 0.3 inch. In places, owing to flow structure, it is more micaceous than in others. Its constituents, in descending order of abundance, are clear colorless potash feldspar (microcline and orthoclase (?); very light smoky quartz with hairlike crystals of rutile and cavities in sheets; milk-white soda-lime feldspar (oligoclase-albite), kaolinized and micacized; muscovite (white mica); biotite (black mica). Accessory: Apatite, rutile. Secondary: Kaolin, a white mica, calcite. It effervesces slightly with muriatic-acid test.

The quarry, opened about 1874, is on the northwest side of a low granite dome and measures about 500 feet in a northeasterly direction by 250 feet across and from 20 to 60 feet in depth.

Rock structure: The sheets, 6 inches to 6 feet thick, dip gently northeast and northwest. There are two sets of joints—(a), strike N. 60° E., vertical, rare; (b), strike N. 60° W., vertical, forms a heading 40 feet wide within 200 feet of the northeast end of the quarry. The rift is reported as horizontal, and the grain as vertical, with N. 60° E. course. A hornblende diabase dike 3 to 4 feet wide crosses the quarry lengthwise within 75 feet of the working face, with a N. 60° E. strike and vertical or steep dip. The granite is darker for 14 feet on one side of the dike and 2 feet on the other. (See p. 58.) Three pegmatite dikes, 14 inches to 5 feet thick, strike about N. 60° W. and dip 45° N. 30° E. to 90°. Some of the granite near the heading of set (b) is porphyritic and has large micas. A flow structure appears also in places. Biotitic knots measure to 5 inches.

Transportation, by siding a mile to Suncook Valley branch of the Boston & Maine Railroad.

The product is used partly for trimmings but mainly for curbing, paving, foundations, and crushed stone for concrete. Specimens: Weston Observatory, foundation and trimmings of Coolidge mill and New Manchester mill of Amoskeag Manufacturing Co., Manchester.

HOOKSETT.

The **Shirley quarry** is near Merrimack River in Hooksett, 6 miles north of Amoskeag, Manchester. Operator, George H. Shirley, 255 Front Street, Manchester.

The granite (specimen D, XXX, 80, a) is a muscovite-biotite granite of very light gray shade and medium texture, with feldspars and micas up to 0.3 inch, the white mica in rhombic crystals. Its constituents, in descending order of abundance, are milky potash feldspar (microcline), slightly kaolinized; clear colorless quartz with cavities; milk-white soda-lime feldspar (oligoclase-albite), much kaolinized and somewhat micacized; muscovite (white mica), mostly in rhombic crystals; biotite (black mica). Accessory: Magnetite, apatite. Secondary: Kaolin, a white mica, calcite. The stone effervesces with muriatic-acid test.

The quarry, opened in 1891, was not visited by the writer.

The stone is brought down Merrimack River 6 miles in a steam tug to the cutting yard at Amoskeag and carted to its destination.

The product is used for curbing, steps, trimmings, and underpinning. Specimens: Trimmings on Amoskeag School and on Manchester Street Railway car barn.

MANCHESTER.

The **Bodwell quarry** is about 2½ miles east-northeast of the city hall in Manchester. Operator, John McCarthy, near R. D. 9, Manchester.

The granite (specimen D, XXX, 83, a) is a biotite granite of light inclining to medium gray shade and of even-grained medium texture, with feldspars up to 0.3 inch, exceptionally 0.5 or 0.7 inch. Its constituents, in descending order of abundance, are clear colorless to translucent potash feldspar (microcline), intergrown with quartz, circular in cross section, slightly kaolinized and micacized; light smoky quartz with cavities in sheets; milk-white soda-lime feldspar (oligoclase-andesine), some of it much kaolinized and micacized; biotite (black mica), some of it chloritized. Accessory: Magnetite, allanite. Secondary: Kaolin, white micas, calcite, chlorite. Much effervescence with muriatic-acid test.

The quarry, opened about 1879, measured in 1909 about 350 feet in a N. 70° E. direction by 65 feet across and 20 to 40 feet in depth.

Rock structure: The sheets, 2 to 6 feet thick, dip 5° S. There is one set of joints only, strike N. 35° W., vertical, spaced irregularly. The rift is reported as horizontal and the grain as vertical, with N. 57° E. course. The quarry is walled on its longer sides by banded quartz-mica diorite gneiss of varying texture and pegmatite lenses. The gneiss foliation strikes N. 45° E. There are tongues and inclusions of this gneiss in the granite. Rusty stain is 2 to 3 inches thick on sheet surfaces.

The product is used locally for foundations and curbing. The quarry has not been operated for several years.

The **Kennard Ledge quarry** is 1½ miles about northeast of the city hall in Manchester. Operator, Evariste Dionne, 368 Lake Avenue, Manchester. Quarry idle.

The granite (specimen D, XXX, 82, a) is a biotite granite of medium buff-gray color and of even-grained medium texture, with feldspars up to 0.3 inch, rarely 0.4 inch, and micas under 0.2 inch. The mica scales lie parallel to the rift. Its constituents, in descending order of abundance, are greenish-gray potash feldspar (microcline), slightly kaolinized; medium smoky quartz with cavities in sheets; buff-gray soda-lime feldspar (oligoclase-andesine), some of it much kaolinized and micacized; biotite (black mica), some of it chloritized; and a little muscovite or bleached biotite. Accessory: Pyrite, magnetite, allanite, apatite, zircon. Secondary: Kaolin, a white mica, chlorite, calcite. There is no effervescence with the muriatic-acid test.

The quarry, opened about 1879, measured in 1909 about 300 feet from east to west by 150 feet across and 60 feet in depth.

Rock structure: The sheets, 6 inches to 9 feet thick, dip low north on the north side and low south on the south side. There is but one set of joints, strike N. 17° W., vertical, spaced 14 to 22 feet, forming a heading 20 feet wide on the south side. The rift is reported as horizontal, and the grain as vertical, with east to west course, both marked. The north wall of the quarry is gneiss with thick dikes and lenses of pegmatite. The foliation strikes N. 80° E. The south wall is of like gneiss. The granite thus appears to be a dike 150 feet wide with north to south strike, cutting a granite gneiss with a nearly east to west foliation. Stain is up to 8 inches thick on sheet surfaces.

The product is used locally for trimmings, curbing, and foundations, for which its marked rift and grain well adapt it.

CONCORD.

TOPOGRAPHY.

The **Concord quarries** are on the east side and top of a north-south ridge known as Rattlesnake Hill, which is said to attain an elevation of 580 feet above the high-water mark of Merrimack River; and they lie within a radius of 1½ to 2 miles from about N. 25° W. to N. 50° W. of the statehouse. Some of them are at the foot of the ridge on North State Street at about the level of the city; others are from 70 to 360 feet above it.

GEOLOGY OF THE QUARRIES.

The salient geologic feature is the occurrence here and there within the granite of inclusions of coarse and fine banded gneisses from a few inches to 30 feet in diameter. The largest of these (see p. 63) is a bright, dark biotite-muscovite gneiss with fine bands of varying shades, according to the proportions of the micas or of the quartz and feldspar. Its feldspar is a soda-lime

(oligoclase-albite to oligoclase), and the accessory minerals are garnet, zircon, apatite, etc. Others are biotite gneisses and consist of alternating bands of very light feldspathic quartzose rock and of dark, coarse, and very fine micaceous schist, the particles of the schist not exceeding 0.02 inch. The geologic age of these gneisses is uncertain. The pegmatite dike that traverses this large inclusion seems, from its relation to the granite, to have been formed before the block was surrounded by granite. Of general interest is also the occurrence of fluorite on joint faces, referred to on page 63, which implies deep-seated origin of the solutions out of which it crystallized and raises the question whether the associated calcite and quartz may not have come from the same source.

Joint planes at the Concord quarries may be divided into eight sets, of which those occurring at the largest number of quarries strike N. 15° E., N. 20°–30° E., N. 60°–65° E., and N. 60°–75° W. Of less frequent occurrence are those striking N. 10° W., N. 45° W., N. 80° E., and east. The number and variety of fractures within one of the headings at the Granite Railway quarry indicate the localization and sharpness of the strain which produced the heading.

Flow structure appears at only one quarry, where it is vertical with a N. 60° W. course. The rift is reported as either horizontal or inclined 5°–15° N. 65°–75° W. or S. 45° W., and the grain as vertical, with east-west course, but exceptionally N. 45° E., N. 70° E., or N. 80° W. The effect of heat and cold on the quality of rift and grain is recognized, and also the fact that the degree of dip of rift is affected by the direction in which the sheet is split. If the splitting is done from the north or south, the rift will prove horizontal, but if from the west it will be inclined. Whether the east-west compressive strain that affects Rattlesnake Hill has anything to do with this deflection is uncertain.

There are pegmatite dikes with courses of N. 30° E., N. 45° E., N. 45° W., and N. 85° W., and segregations of very fine porphyritic granite. (See p. 201.)

"CONCORD GRANITE."

The following combines all the more detailed descriptions of rough and polished specimens and thin sections given on pages 197, 199.

"Concord granite" is a muscovite-biotite granite of medium bluish-gray color. The significance of the term "medium gray" becomes apparent upon comparing the terms applied to the principal light granites of New England. The granite of Hallowell, Maine, is light gray; the "white granite" of North Jay, Maine, is very light gray; and the granite of Bethel, Vt., is white mottled with gray. The general shades of these light or whitish granites form a descending series in which "Concord granite" stands fourth, the granite of Bethel, Vt., being white with a mottling of shade. The texture of "Concord granite" is fine to medium, somewhat porphyritic, with sparse slender, isolated feldspars up to 0.5 inch. Although the micas occur in very minute particles, especially the biotite, they measure up to 0.2 inch and exceptionally 0.4 inch. Its constituents, in descending order of abundance, are slightly bluish translucent potash feldspar (microcline, usually in longish twins, and some orthoclase), inclosing particles of quartz and of soda-lime feldspar (in some specimens these minerals with biotite are zonally arranged within a crystal of feldspar); clear to pale amethystine quartz with hairlike crystals, probably of rutile, and with cavities in sheets which in some sections are parallel; milk-white striated soda-lime feldspar (oligoclase-albite), more or less kaolinized and centrally micacized; white potash mica (muscovite); and black mica (biotite), some of it chloritized, generally in smaller scales than the muscovite.

In some specimens the mica plates have their flat sides parallel to the rift direction; in some the biotite appears to predominate over the muscovite, possibly owing to the different alinement of its scales. Accessory: Magnetite, apatite, zircon (some in doubly terminated slender prisms), and rutile. Purple and white fluorite occurs here and there on and near joint planes. Calcite and quartz are associated with it on these joints. Secondary: Kaolin, muscovite in veinlets, a white mica without potash, chlorite, and calcite.[81]

But one chemical analysis of "Concord granite" is available. That is given on page 199. The specific gravity of the stone was determined by Crosby as 2.64 and 2.65, averaging 2.65, or 155.6 pounds per cubic foot.

George Steiger and W. T. Schaller, chemists, of this Survey, find as the result of two tests that "Concord granite" contains from 0.15 to 0.17 per cent of CaO (lime) soluble in hot dilute acetic acid, which indicates a content of 0.26 to 0.30 per cent of $CaCO_3$ (calcium carbonate), and the microscope also shows the presence of carbonate.

Two tests of compressive strength, made at the United States arsenal at Watertown, Mass., show a compressive strength of 30,830 pounds to the square inch with pressure applied at right angles to the rift, and of 23,860 pounds with pressure applied parallel to the rift. There is thus a loss of 12.5 per cent of compressive strength in the rift direction. A more recent test made at the same place gave this stone a compressive strength of 23,670 pounds, direction of rift and grain not stated.

The polish of "Concord granite" is fair, but the abundant mica plates and the size of some of them do not favor the durability of the polish under long-continued outdoor exposure. The muscovite appears much darker when polished. No pyrite was detected in the polished specimens or thin sections, although the chemical analysis indicates its probable presence. There is considerable contrast between the rough and hammered faces. The general bluish cast of the granite is marked, particularly on the polished face, but the rough face becomes lighter on continued exposure. There is some variation in the amount of mica apparent on the different faces of a block, as well as a difference in the actual amount of black mica and in the sparseness of the large feldspars in the stone from different quarries. Only on close inspection do strong contrasts appear between the bright muscovite plates, the fine black biotite scales, and the glassy feldspar.

QUARRIES.

The **New England Granite Works quarry** is in the upper part of Rattlesnake Hill, roughly northwest of Concord. Operator, New England Granite Works, 20 Ferry Street, Concord.

The granite (specimens D, XXVIII, 39, a, b, f, g), "Concord granite," is a muscovite-biotite granite of medium bluish-gray color and fine to medium, somewhat porphyritic texture, with sparsely disseminated larger feldspars up to 0.4 inch (exceptionally 0.5 inch) and micas from very minute size up to 0.2 inch (exceptionally 0.4 inch). It consists, in descending order of abundance, of a slightly bluish translucent potash feldspar (microcline, mostly in long twins, less orthoclase), inclosing quartz and soda-lime feldspar particles; clear to faintly amethystine quartz with abundant hairlike crystals, probably of rutile, also with sheets of cavities; milk-white more or less kaolinized and micacized soda-lime feldspar (oligoclase-abite) containing rare particles of

[81] A microscopic description of Concord granite by G. W. Hawes will be found in his Mineralogy and lithology of New Hampshire, which forms vol. 3, pt. 4, of C. H. Hitchcock's Geology of New Hampshire, 1878.

carbonate, probably calcite; white potash mica (muscovite); and black mica (biotite), mostly in smaller scales than the muscovite or with their flat sides at right angles to the muscovite scales. Accessory: Magnetite (some within biotite), apatite, zircon, and rutile. Secondary: Kaolin, muscovite in veinlets, white mica without potash, and calcite.

George Steiger, a chemist of this Survey, finds that this granite contains 0.15 per cent of CaO (lime) soluble in hot dilute acetic acid, which indicates a content of 0.26 per cent of $CaCO_3$ (calcium carbonate); the presence of this carbonate is also indicated by the microscope.

A test of the compressive strength of this granite, made at the United States arsenal at Watertown, Mass., in 1907, gave the following results: A cube of approximately 2-inch edge showed the first crack at 86,000 pounds and was crushed at 94.200 pounds, thus having an ultimate compressive strength of 23,670 pounds to the square inch. It does not appear whether the pressure was applied in the rift or grain direction.

The granite of this quarry appears to be more biotitic and to have its larger feldspars more sparse than the stone of the other Concord quarries.

The quarry, opened in 1812, was in 1906 about 350 feet from northeast to southwest, by 300 feet across, and had a working face on the southwest 130 feet in height.

Rock structure: The sheets, from 6 inches thick in the upper 30 feet of the working face to 40 feet at the bottom, dip 10°–15° SE. Some of the sheets, owing to their freedom from rusty discoloration, are regarded by the foremen as of recent origin and are called "strain sheets;" and even now a northwest-southeast compressive strain occasionally extends these sheets. (See p. 32.)

There are two sets of joints—(a), strike N. 62° E., vertical, forms headings on the northwest and southeast sides and recurs in the middle, but is apt to be discontinuous; (b), strike N. 45° W., dip 35° NE., represented by only two on the northwest wall 5 feet apart. The rift is reported as horizontal, and the grain as vertical and exactly east-west. Two 6-inch pegmatite dikes, 20 feet apart, and several an inch thick traverse the quarry vertically with a N. 30° E. course. The thick ones are banded, consisting of a central 1½ to 2 inch band of aplitic material with a half-inch border on one or both sides made up of coarse pegmatite, milk-white oligoclase and microcline, and smoky quartz. Very fine garnets occur throughout these dikes, some in bands, and here and there a small beryl. There are also half-inch muscovitic veins, "sand streaks" (p. 74), striking N. 45° W. and consisting of a central band of muscovite and quartz, with borders of quartz and feldspar. Gray and black knots of the micas measure up to 6 by 5 inches. Light rusty stain measures from 6 inches to 2 feet on the sheet surfaces, but for 100 feet vertically in the center of the quarry the sheets have little or none of it.

Transportation, by track five-eighths mile to siding of Boston & Maine Railroad.

The product consists mainly of building stone. Thin sheets and waste furnish about 100,000 paving blocks annually as a by-product. Specimen structures: The four outer walls and the covered driveway of the Congressional Library and the outside and inner court walls of the basement of the United States Senate Office Building, Washington; Blackstone Library, Chicago; Bankers Trust Co., Wall Street, and Christian Science Church, New York; Camden County courthouse, Camden, N. J.; city and county building, Pittsburgh, Pa.; Adelphia Hotel, Philadelphia; Assabet River bridge, Northboro, Mass.; Early Settlers monument, Galveston, Tex.; receiving tomb, Greenwood Cemetery, Wheeling, W. Va.; Stassforth mausoleum, Evergreen Cemetery, Los Angeles, Calif.; New Hampshire Historical Society Building, Concord, N. H.

The **Granite Railway or Upper Swenson quarry**[82] (of Concord) is on Rattlesnake Hill, about N. 40° W. from the statehouse at Concord and 200 feet above it. Operator, John Swenson Granite Co., Concord.

The granite (specimens D, XXVIII, 40 c, e), "Concord granite," is a muscovite-biotite granite of medium bluish-gray color and fine to medium, somewhat porphyritic texture, with feldspars up to 0.5 inch and mica plates to 0.2 inch. Feldspar appears to be relatively more abundant and biotite less so than in the stone of the New England Granite Works quarry. In other respects the two granites are identical. A section cut at right angles to the rift shows that the mica plates, both black and white, lie with their flat sides parallel to the rift.

The following analysis of this granite was made by Sherman & Edwards, chemists, from a "thoroughly composite sample carefully selected" by W. O. Crosby, of the Massachusetts Institute of Technology. This analysis forms part of a report made by him for the firm in 1907, and is published here merely for reference.

Analysis of "Concord granite" from Swenson quarries.

Silica (SiO_2)	74.47
Alumina (Al_2O_3)	14.15
Iron sesquioxide (Fe_2O_3)	1.16
Iron oxide (FeO)	1.21
Magnesia (MgO)	.63
Lime (CaO)	1.70
Soda (Na_2O)	1.97
Potash (K_2O)	4.14
Sulphur (S)	.27
Carbonic dioxide (CO_2)	.25
Water not combined (H_2O)	.06
Water combined (H_2O)	.20
	100.21

Crosby, in the same report, gives two determinations of specific gravity as 2.64 and 2.66, average 2.65, which is equivalent to 155.6 pounds to the cubic foot.

W. T. Schaller, a chemist of this Survey, finds that this granite contains 0.17 per cent of CaO (lime) soluble in hot dilute acetic acid, which indicates the presence of 0.30 per cent of $CaCO_3$ (calcium carbonate).

Compression tests made at the United States arsenal at Watertown, Mass., in 1906 show it to have an ultimate compressive strength of 30,830 pounds to the square inch with pressure applied at right angles to the rift, but of 23,860 pounds with pressure applied in the direction of the rift, the rift thus weakening the stone 12.5 per cent when pressure is applied parallel to it.

The quarry, opened in 1863, measured in 1906 about 500 feet in a north-northeasterly direction by 400 and 200 feet in width and from 10 to 100 feet in depth.

Rock structure: The sheets are irregular, lenticular, 4 inches to 14 feet thick, but mostly from 2 to 7 feet, and dip northwest at a low angle. There are two sets of joints—(a), strike N. 20° E., dip 70°–75° E., spaced 10 to 100 feet, forms the west wall and a heading 50 feet wide on the east side; (b),

[82] This quarry owes its first name to the fact that it was originally operated by the Granite Railway Co., of Quincy, Mass., referred to on p. 329.

strike N. 65° W., vertical or dip 75° S., spaced 10 to 300 feet, forms the north wall and a heading 6 to 15 feet wide on that side. The rift is reported as dipping 15° W., with a strike of N. 5°–10° E., and the grain as vertical east-west. In summer time it is not necessary to follow the grain closely in splitting. There are pegmatite dikes up to 1½ inches wide. Segregations of the micas are said to be very rare and to measure only 4 inches. Rusty stain is up to 8 inches wide, but confined to the proximity of headings. A little east-west compressive strain is reported. The joint faces of headings (b) are dull greenish, owing to chloritization of biotite and the formation of fibrous muscovite in the feldspar and between the particles. The soda-lime feldspars also contain chlorite and carbonate. Other joint faces of the same set carry secondary quartz and calcite crystals and apparently also fluorite, deep purple and white. (See p. 83.)

Transportation, by cart one-third mile to cutting sheds on siding of Boston & Maine Railroad.

The product is used for buildings and monuments. Specimens: Institute of Arts and Sciences, Manchester, N. H.; city hall and Christian Science Church, Boston; Northampton County Savings Bank, Easton, Pa.; Lehigh County courthouse, Allentown, Pa.; Medico-Chirugical Hospital, Eighteenth and Cherry streets, Philadelphia; post offices at Dayton, Ohio, Lincoln, Nebr., Adrian, Mich., and Hammond, Ind.; pedestal of the Monaghan monument, Spokane, Wash.; New Hampshire soldiers' monument, Vicksburg, Miss.; pedestal and exedra of McKinley memorial, McKinley Park, Chicago; and electric station of New York Edison Co., East Thirty-ninth Street, New York.

The **Lower Swenson or Hollis quarry** is about 600 feet northeast of the last and 70 feet below it. It is operated by the same company.

The granite is identical with that of the upper quarry, just described. The quarry, opened about 1864, measured in 1906 about 450 feet north and south by 300 feet across and from 40 to 50 feet in depth.

Rock structure: The sheets, 6 inches to 35 feet thick, are irregular, lenticular, and horizontal or dip 15° W. There are two sets of joints—(a), strike N. 25° E., dip 65°–70° E., spaced 10 to 50 feet, forms headings on the west and east sides and another 50 feet of the west wall; (b), strike N. 65° W. to east-west, about vertical, spaced 20 to 75 feet, forms the northeast wall. There are several inclusions of banded gneiss; one 3 feet 6 inches by 2 feet; another, originally much larger, now measures 4 feet 6 inches in diameter and is roughly quadrangular. Part of this is pegmatitic and part a biotite gneiss, with soda-lime feldspar (oligoclase-andesine) and garnets. In the finer parts the particles do not exceed 0.37 millimeter in diameter. The rift and grain are reported as the same as at the upper quarry. One-inch pegmatite dikes cross the quarry diagonally. Rusty stain on the upper sheets is up to 8 inches thick. The granite along heading (a) on the west wall is much kaolinized and in places very limonitic. The surfaces have frostlike crystallizations (dendrites), probably of limonite also.

The product of this quarry has been combined with that of the Upper Swenson quarry.

The **Fox quarry** is on Rattlesnake Hill, 110 feet above North State Street, N. 43° W. from the statehouse, and about half a mile N. 40° E. from the New England Granite Works quarry. Operator, Thomas Fox, 272 North State Street, Concord. Idle in 1921.

The granite, "Concord granite," is a muscovite-biotite granite of medium bluish-gray color and fine to medium, somewhat porphyritic texture, resembling that of the Upper Swenson quarry more than that of the New England Granite Works quarry. (See p. 199.)

The quarry, opened in 1884–85, a plan of which is given in figure 40, measured in 1906 about 200 feet and 300 feet by 175 feet across and from 40 to 70 feet deep.

Rock structure: The sheets, 2 to 20 feet thick, are, for this region, exceptionally regular, and dip 10° SW. There are three sets of joints. (See fig. 40.) A, vertical to steep, east-southeast, spaced 3 to 30 feet, forms east and west walls and the headings on the east side and center. B, vertical to steep, east, spaced 10 feet and over. C, spaced 10 to 70 feet, apt to be discontinuous. The rift is reported as dipping 5°–7° SW., and the grain as vertical, with a N. 70° E. course. The stone splits more easily along the rift in winter than in summer. In the northern part a 10-foot band of granite, without the bluish tint of the rest, strikes N. 60° W. and dips 90°. The cause of the difference is not clear, unless it is the micacization of the potash feldspar. This band contains zonally arranged particles of quartz and oligoclase. Its course presumably indicates the flow direction of the granite. On one or both sides of it is an inch vein of muscovite. Pegmatite dikes are up to 1½ inches thick. There are spheroidal segregations, from 6 inches to 3 feet by 2 feet 6 inches, of a porphyritic granite of bluish-gray color, darker than any "Concord granite." The matrix is fine-textured (particles 0.18 to 0.74 millimeter); the feldspars measure up to 0.4 inch and the mica to 0.2 inch. The constituents are the same as those of "Concord granite." The sheet surfaces are mostly free from rusty stain, and it is said never to exceed 4 inches in thickness. One of the joint faces carries chlorite, calcite, and pyrite.

Transportation, by cart one-fourth mile to siding of Boston & Maine Railroad, or three-fourths mile to cutting shed.

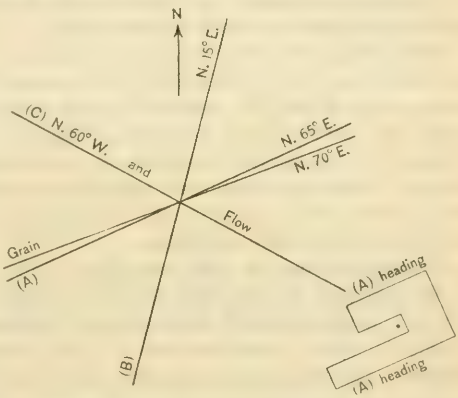

FIGURE 40.—Structure and plan of Fox quarry, Concord, N. H.

The product is used for buildings and monuments. Specimens: Church of Christ, Scientist, Sheldon Library, St. Paul's School, Concord; soldiers' monument, Warner, N. H.; Carpenter tomb, Manchester, N. H.; entrance to Forest Lawn Cemetery, Buffalo, N. Y.

The **Perry quarry** is on Rattlesnake Hill, N. 50° W. from the statehouse and 360 feet above North State Street. This is the most southerly of the Concord quarries. Operators, Perry Bros., Concord.

The granite, "Concord granite," is a medium bluish-gray muscovite-biotite granite of fine to medium, somewhat porphyritic texture, closely resembling that of the New England Granite Works quarry described on page 197.

The quarry, opened in 1873, measured in 1906 250 feet N. 75° W. by 125 to 250 feet N. 10° E., and from 60 to 100 feet in depth.

Rock structure: The sheets, 1 to 18 feet thick, are about horizontal. There are four sets of joints—(a), strike N. 10° E., dip steep east, spaced 5 to 20 feet; (b), strike N. 75° W., vertical, spaced 18 to 35 feet; (c), strike N. 30° E., dip 50° E., spaced 200 feet; (d), strike N. 45° W., dip 75° S. 45° W., occurs only at the northeast corner. The rift is reported as horizontal, and the grain as vertical, with N. 80° W. course. A 4 to 5 inch pegmatite dike has a N. 85°

W. course and vertical dip. Rusty stain does not exceed 4 inches and is absent from some sheets.

Transportation, by cart 3 miles to cutting shed on Boston & Maine Railroad.

The product is used mostly for monuments. Specimen: George Fogg monument, Blossom Hill Cemetery, Concord.

The **Henneberry quarry** is on Rattlesnake Hill, one-fourth mile west of North State Street and 70 feet above it, at a point one-fourth mile north of the State prison. Operator, Thomas Fox, 272 North State Street, Concord. Idle in 1921.

The granite (specimens D, XXVIII, 49, a, c), "Concord granite," is a muscovite-biotite granite of medium bluish-gray color and fine to medium, somewhat porphyritic texture, with feldspars up to 0.5 inch and white mica scales up to 0.2 inch. This stone resembles more closely that of the New England Granite Works quarry than that of the Swenson quarries, being more micaceous and less feldspathic than the latter, but the black mica scales are generally finer than in the former, so that it has a larger number of fine particles. The constituents are the same as in the sections described on pages 197, 199.

The quarry, opened in 1900, was in 1906 about 200 feet N. 25° E. by 100 feet across and from 50 to 65 feet deep.

Rock structure: The sheets, 2 to 15 feet thick, are somewhat irregular and horizontal or dip 17°–30° NE. There are two sets of joints—(a), discontinuous, strike N. 25° E., spaced 3 to 15 feet, forms a heading at the northeast end; (b), strike about northeast, diagonal, spaced 12 to 25 feet. The rift is reported as horizontal or nearly so, and the grain as vertical with a northeast strike. Three garnetiferous pegmatite dikes, 1 to 4 inches thick, in a space of 2½ feet, strike about N. 45° W. and dip 60° SE. Rusty stain is about 4 inches thick on sheet surfaces.

Transportation, by cart, one-eighth mile to Boston & Maine Railroad.

The product is used entirely for monuments. Specimens: Fay sarcophagus, Dewitt, Iowa; Sielaff sarcophagus, Milwaukee, Wis.; Raines sarcophagus, Memphis, Tenn.; McElwee sarcophagus, Homer, Ill.; Alten cross, Elyria, Ohio; Crippen sarcophagus (elaborately carved), Blossom Hill Cemetery, Concord.

ROCKINGHAM COUNTY.

AUBURN.

The **Auburn quarry** is 7 miles east of Manchester, in the township of Auburn. Operators, Perry Bros., Concord.

The granite (specimens, D, XXVIII, 46, a, b), "deep-pink Auburn," is a quartz monzonite of medium pink-buff color with very fine black dots. Its texture is fine, with feldspar and mica up to 0.1 inch. Its constituents, in descending order of abundance, are slightly pinkish potash feldspar (orthoclase and microcline); almost if not quite as abundant, clear to milk-white soda-lime feldspar (oligoclase), some of it kaolinized and micacized; smoky quartz; and biotite (black mica), some of it chloritized and bleached. Accessory: Magnetite, apatite, and zircon. Secondary: Kaolin, a white mica, chlorite, and hematite stain.

The stone takes a fair polish, and the hammered face by its lightness offers not a little contrast to the rough and polished faces. It is used for monumental work.

STRAFFORD COUNTY.

ROCHESTER.

The **Langmaid quarry**, in Rochester Township, 5 miles northwest of Dover, is no longer operated.

The granite (specimen D, XXX, 84, a) is a biotite granite of very light gray shade, with close dark specks, and of even-grained medium texture, with feldspar up to 0.3 inch and micas to 0.2 inch. Its constituents, in descending order of abundance, are clear to translucent potash feldspar (microcline and orthoclase); medium smoky quartz with cavities in sheets and hairlike crystals of rutile; milk-white soda-lime feldspar (oligoclase-albite), most of it kaolinized and micacized; biotite (black mica), some of it chloritized; and a little muscovite or bleached biotite. Accessory: Magnetite, rutile. Secondary: Kaolin, a white mica, chlorite, calcite. It effervesces slightly with muriatic acid test.

This is a constructional granite with marked contrast of shade between its smoky quartz and milk-white feldspar.

The quarry, opened before 1879, measured in 1909 about 300 by 90 feet and from 12 to 15 feet deep.

Rock structure: The sheets, 1 to 8 feet thick, are horizontal. There are three sets of joints—a longitudinal, a transverse, and a diagonal set—spaced generally 10 to 20 feet. The rift is reported as horizontal, and the grain as vertical, with north-south course. There are several pegmatite dikes about a foot thick. Rusty stain is 1 to 3 inches but in places 8 inches thick on sheet surfaces.

Transportation, by cart 5 miles to Dover or Rochester.

The product was used for bases, trimmings, and faces. Specimen: Some of of the trimmings of the courthouse at Dover, N. H.

SULLIVAN COUNTY.

SUNAPEE.

The **Spectacle Pond quarry** is at the southeast corner of Sunapee Township, about a quarter of a mile south of Spectacle Pond and the same distance southwest of Edgemont (formerly Mount Sunapee) station. (See Sunapee topographic map, U. S. Geol. Survey.)

The granite (specimen D, XXX, 78, a) is a biotite-muscovite granite of light buff-gray color and of even-grained fine texture, with feldspars up to 0.2 inch, rarely 0.25 inch, and micas under 0.1 inch. Its constituents, in descending order of abundance, are clear colorless potash feldspar (microcline and orthoclase); light smoky quartz with hairlike crystals of rutile and with cavities in sheets and cracks parallel thereto; cream-colored soda-lime feldspar (oligoclase-albite), more or less kaolinized and micacized; biotite (black mica); muscovite (white mica). Accessory: Garnet, apatite, rutile. Secondary: Kaolin, a white mica. No effervescence with muriatic-acid test.

This is a fine-grained monumental granite. Its color may be less buff and even bluish farther below the surface.

The quarry, when opened in 1909, was 75 feet square and 3 to 8 feet deep.

Rock structure: The sheets, 1 to 5 feet thick, dip 15° about northeast. There are three sets of joints—(a), strike N. 10° E., dip 80° W., spaced 5 to 10 feet, forms a heading on the east side; (b), strike northeast, dip 65° NW., spaced 10 to 25 feet, forms a heading at the southwest corner; (c), strike N. 30° E., dip 70° N. 60° W., forms a heading 10 feet wide through the middle of the quarry. The rift is reported as horizontal, and the grain as vertical, with nearly east-west course. A quartz vein up to 5 inches thick crosses the middle of the quarry, with N. 70° E. strike. Rusty stain is up to 4 inches thick on sheet surfaces. The quarry is no longer operated.

The **Perry Sunapee quarry** is on the top of a 200-foot knoll half a mile west of Burkehaven, on Lake Sunapee, and three-fourths of a mile south-south-east of Sunapee village, in Sunapee Township. (See Sunapee topographic map, U. S. Geol. Survey.) Operators, Perry Bros., Concord.

The granite (specimens, D, XXVIII, 47, a, b), "light Sunapee," is a biotite-muscovite granite of a light-gray, slightly bluish color and very fine to fine texture, with feldspars up to 0.15 inch and mica to 0.1 inch. Its constituents, in descending order of abundance, are clear colorless potash feldspar (microcline and orthoclase, the latter with hairlike crystals, probably of rutile, both being intergrown with quartz circular in cross section); clear colorless quartz, also with rutile needles; translucent to milk-white soda-lime feldspar (oligoclase-albite), somewhat kaolinized and intergrown with quartz; biotite (black mica); and muscovite (white mica). Accessory: Magnetite, garnet, zircon, and rutile. Secondary: Kaolin and carbonate.

This, as will be seen by comparing the descriptions, is finer grained than "Concord granite." It lends itself well to fine carving. Its particles are too fine to afford contrasts. It takes a fair polish.

The "black granite" (specimen D, XXVIII, 48, a, b), "black pearl" or "dark Sunapee," is a quartz diorite of very dark bluish-gray color and fine, inclining to medium texture, with feldspars up to 0.2 inch. Its constituents, in descending order of abundance, are clear colorless to milk-white soda-lime feldspar (oligoclase-andesine to andesine), but little kaolinized, rarely intergrown with quartz; biotite (black mica); clear colorless quartz (possibly equal in amount to feldspar); and titanite. There is so much of this molasses-colored mineral present that it is easily seen with a loop. Accessory: Magnetite (ilmenite?), pyrite, allanite, and zircon. Secondary: Kaolin, epidote (about allanite), calcite, and hematite. It effervesces slightly with muriatic acid test.

When polished the rock appears black mottled with white. The polish is poor owing to the large size and abundance of mica. It shows magnetite and a little pyrite. The hammered face is light gray and thus is in marked contrast to both rough and polished faces. The stone is used for monuments and is suitable for inscriptions.

The quarry, opened in 1869, measured in 1906 about 150 by 100 feet and from 15 to 30 feet in depth.

Rock structure: The sheets, 6 inches to 3 feet thick, are undulating. There are no joints. The rift is probably horizontal, and the grain vertical, with N. 80° W. course. A pegmatite dike up to 30 inches thick, strike N. 30° E., vertical or steep, forms part of the east wall. A 3-foot dike striking about east forms the north wall. Other pegmatite dikes up to 6 inches thick, strike N. 50°–70° E., recur at intervals of 5 to 20 feet. A vertical porphyritic granite mass, also striking N. 30° E., forms the west wall. Two large inclusions of quartz-mica diorite gneiss occur near the south end of the east wall, apparently in a coarser granite. The larger, 10 feet long and of very irregular outline, is crossed by meandering quartz veins. These inclusions appear to lie not within the fine granite of the quarry but within a coarser granitic rock adjoining or crossing it. The diorite consists of andesine, biotite, quartz, and titanite. The other inclusion back of the northeast corner of the quarry is of similar rock but contains hornblende. These diorites resemble that of specimens 48, a, b, described above. A disused quarry of that rock occurs a little north of the Perry light-granite quarry. A coarse porphyritic granite occurs also on the same hillock. A little west of Sunapee on the road to Newport a coarse porphyritic granite, a fine-grained granite, and a dark schistose rock all occur in a single outcrop. The relations of the diorite gneiss to the fine and the coarse granite were not further investigated.

Transportation, by cart more than 3 miles to Sunapee station, on Claremont branch of Boston & Maine Railroad.

The product is used for monuments, which are finished at the firm's cutting shed at Concord. The quarry is operated only occasionally.

MAINE.

THE OCCURRENCE OF GRANITE IN MAINE.

By George Otis Smith.

GEOGRAPHIC DISTRIBUTION.

Areally, granite is perhaps the most abundant rock in Maine. Slates, schists, sandstones, and limestones of various types occur in the different sections of the State, but the mountains and hills of the interior and the islands and headlands of the coast for the most part all exhibit slopes and cliffs of massive granite. Even where the exposures are of other rock varieties the notable abundance of granite dikes and quartz veins indicates the presence of granite at no great distance. Not only is this rock most conspicuous, but its importance in both the geology and the industry of the State can hardly be overestimated.

The areal distribution of the granite is somewhat irregular, as may be noted on the map accompanying this report (Pl. IX). Three general granitic regions may be distinguished for convenience of description—that of the western tier of counties, that of the eastern part of the State, and the Mount Katahdin area, in the north-central part of the State. In addition to these larger regions there should also be mentioned three small areas in Lincoln, Kennebec, and Somerset counties, which are intermediate in position between the three main regions.

The granite areas of the western region are not widely separated, and the largest of these areas as outlined on the map is not all granite, although, as will be explained in a later paragraph, the intrusive granite forms the larger part of the rock exposed within these limits. The northernmost of these granite masses is exposed in the elevated country that forms the divide between the Chaudiere drainage basin on the Canadian side of the international boundary and the headwaters of Androscoggin and Dead rivers in the northern part of Franklin County. South of this is a much larger area of granite, extending from the western part of Somerset County across Franklin into Oxford County and including prominent peaks, like Mount Bigelow and Saddleback Mountain, as well as the rugged country south of the Rangeley Lakes. South of this is a large, irregular-shaped area of metamorphic rocks—gneisses and schists—more or less thoroughly impregnated with granite, which extends

southward and eastward through seven counties, reaching the coast at Casco Bay on the west and Penobscot Bay on the east. Southwest of this area is a mass of granite, which constitutes the eastern extension of the White Mountain massif of New Hampshire and reaches the coast at Casco Bay, Cape Porpoise, and York Cliffs.

The Mount Katahdin area of granite lies wholly within the forested region of northern Maine, and therefore its exact boundaries are unknown. At the northeast end of the area is the highest elevation in the State, Katahdin, 5,268 feet above the sea, a typical granite mountain. To the southwest, possibly connected with this area, is the granite near Lake Onawa, where the rock is well exposed in a deep cut of the Canadian Pacific Railway.

In the eastern counties three extensive granitic areas may be distinguished. Of these the northernmost extends southwestward from New Brunswick across the northern portions of Washington and Hancock counties into Penobscot and is almost wholly forested country. Southeast of this is the horseshoe-shaped granitic area of Hancock County, which crosses into Washington County near Cherryfield. On the west the outlying Mount Waldo mass may represent an extension of the same granite, although connecting exposures along Penobscot River below Bucksport have not yet been observed. In the Hancock County area the granite can be traced from the shore of Eggemoggin Reach northward along a line of prominent hills, which are best seen from the Maine Central Railroad near Green Lake. North of Aurora these granite hills have less relief, but east of that place the belt extends southward with increasing ruggedness of topography, Tunk Mountain, near the Washington County Railroad, being characteristic of this southern portion. The other area of granite in eastern Maine is the belt extending from New Brunswick across the St. Croix, thence southwestward to the coast at Addison, and thence along the coast to Penobscot Bay. Within this belt are included several large islands—Swans, Deer, and Vinalhaven—and the mountains of Mount Desert owe their topographic prominence to the massive character of the granite composing them.

Of the smaller areas of granite not included within the three groups described above, that in Lincoln County comprises the town of Waldoboro and islands at the head of Muscongus Bay. The Hallowell-Augusta area in Kennebec County, the North Jay and Phillips area in Franklin County, and the Hartland and Norridgewock areas in Somerset County represent the larger of many small intrusive masses of granite in central Maine. With these should be mentioned the granite occurring in Aroostook County, about 12 miles west of Houlton.

In the preparation of the map (Pl. IX) showing the distribution of the granite, as described above, the data used have been largely the

MAP SHOWING THE DISTRIBUTION OF GRANITE AND RELATED ROCKS IN MAINE

1922

results of areal mapping for folio publication by E. S. Bastin, C. W. Brown, and the writer, and of general reconnaissance by the writer, assisted by Mr. Bastin. In the more northern areas the work by H. E. Gregory and the earlier mapping by C. T. Jackson and C. H. Hitchcock have been utilized to supplement this recent work. Mr. Brown also contributed the results of recent observations in the vicinity of Mount Katahdin.

GEOLOGIC RELATIONS.

Wherever the granites of Maine have been studied in any degree of detail, their relations are plainly those of intrusion into part, at least, of the adjacent formations. Evidence that the granite is the younger rock is found in the tendency shown by some of the granite areas (see Pl. IX) toward elongation in a northeast-southwest direction, parallel to the general trend of the main structural features of the region, but more conclusive evidence is found in the fact that the granite actually cuts across the bedding of the sedimentary rocks and has in some localities produced in them a very considerable amount of alteration. Bordering the granite in Franklin County, for example, and in some other parts of the State are andalusite schists which plainly represent sedimentary strata metamorphosed by the granite. In many regions, as will be described later, the granite masses are bordered by gneisses which were formed by the injection of granitic material along the foliation planes of sedimentary schists. Thus the general relations throughout the State suggest that the granites are relatively the younger rocks.

The feature which is perhaps the most significant in the geologic relations of the granites to the other rocks of the State is the great contrast between the sharpness of certain granite borders and the indefinite character of others. In the vicinity of Bluehill and Brooksville, in Hancock County, for example, the contact is absolutely sharp, pure granite being succeeded within a foot by schists unmixed with granite. Along such sharp borders, too, the granite usually preserves its normal texture up to the very contact, and the surrounding rocks show almost no effects of contact metamorphism. In striking contrast to this are the broad contact zones which characterize most of the granite masses lying farther west. In the Rockland region, for example, the Sprucehead-Clark Island granite area is bordered on the northwest by a zone 3 to 4 miles in width in which sedimentary slates and schists are intimately associated with injection gneisses, basic granites, fine-grained granite, pegmatite, diorite, gabbro, and diabase. These igneous rocks were plainly derived from the granitic magma and are most abundant in those portions of the contact zone which lie nearest to the areas of pure

granite. A granite area near South Penobscot, in Hancock County, is almost completely surrounded by a border zone from one-fourth mile to 1½ miles in width in which the rocks are largely diorite and gabbro with small amounts of igneous gneiss and fine-grained granite.

Some hint as to the cause of this contrast in the character of granite borders in different regions is obtained from a study of the rocks in the southwestern part of the State, especially in Sagadahoc, Cumberland, and Oxford counties and the southern part of Kennebec County. Here, as indicated on the map (Pl. IX), there are considerable areas which contain no large continuous masses of normal granite but in which the prevailing sedimentary schists have been invaded in the most intimate manner by dikelike or irregular masses of pegmatite and fine-grained granite and in many places have been given a gneissic texture by the injection of granitic material. The areas of intrusion and injection pass gradually into the larger areas of nearly pure normal-textured granite shown on the map. To explain such intimate injection and intrusion in areas far removed from any outcropping masses of pure normal granite it seems necesary to assume that a granite mass underlies these rocks at no great distance below the present surface and that such invaded areas constitute in reality portions of the "roof" of great granite batholiths.

It seems almost certain that the escape of gases and water vapor and the differentiation of basic rocks from the granitic magma would proceed much more rapidly from the upper surface of a buried magma than from its sides. It is to be expected, therefore, that portions of the "roof" of such granite masses should be particularly characterized by the abundance of pegmatites, diorite, gabbro, etc., and by notable contact metamorphism of the sedimentary rocks through which these forced their way. The sharpness of other granite contacts is readily explained by supposing that they represent the side contacts of the granite batholiths, where the gases and water vapor escaped from the magma laterally in much less volume and where the accompanying metamorphic effects were very much less than at the upper surface.

The geologic history of the great granite intrusions of Maine may therefore be summarized as follows:

All the granite masses now exposed solidified below the surface as it existed at the time when they were intruded. The depth at which they solidified varied in different places. Erosion gradually removed the rocks covering some of the masses and has in some places even revealed their deeper portions, so as to show the sharp lateral contacts. In other places all or a part of the "roof" of the

granite masses still remains. The present land surface therefore truncates the various granite batholiths at different horizons. It is highly probable that a further erosion of 500 to 1,000 feet would expose much larger areas of granite than now appear.

All the granites of Maine were formerly supposed to have been intruded during a single great period of igneous activity and to be of the same general geologic age. This conclusion was based on their general lithologic similarity and on the presumed continuity, at no great depth below the surface, with the granite of neighboring areas, as stated above. There is little doubt, for example, of the contemporaneity of the granite of the Perry Basin, on the eastern border of the State, with that of Vinalhaven, as a belt of granite extends with slight interruptions from one of those localities to the other. It was thought, therefore, that the greater part of the State is underlain by a huge granite batholith with an irregular upper surface, exposed by erosion in many areas but elsewhere covered by uneroded portions of the "roof."

The age of the belt of granite just mentioned is approximately known, as the Silurian strata of the Perry Basin district contain no pebbles of granite, but such pebbles, plainly derived from the neighboring granite masses, are abundant in the conglomerate at the base of the Perry formation, which is of late Devonian age. The granite is therefore late Silurian or early Devonian, and this conclusion is strengthened by the evidence in the Vinalhaven district, where the granite is intruded into surface volcanic rocks of Niagaran age.

In southwestern Maine, however, the rocks into which most of the granites are intruded are now believed to be Carboniferous, because of their strong lithologic similarity to the Carboniferous strata of central Massachusetts and their virtual continuity with those strata across southeastern New Hampshire. Hence most of the granites of that part of the State are much younger than those of the eastern part. At present, therefore, although all the granites of Maine are regarded as of Paleozoic age, they are thought to be separated into at least two eruptive groups, one middle Paleozoic and the other probably late Paleozoic.

DISTRIBUTION OF GRANITE QUARRIES.

The map (Pl. IX) shows the location of the principal quarries and groups of quarries and prospects, which include 115 separate openings, and also the relation of these to the rock areas described above by Doctor Smith. A number of unimportant paving-block and underpinning quarries have been overlooked or intentionally omitted. A typical one-man paving-block quarry which from its changing location is called in Maine "a motion" is shown in Plate XVIII, *B*.

Quarries of granite proper.—With the exception of the important quarries at Hallowell, Kennebec County, and North Jay, Franklin County, and the minor ones at Fryeburg and Bryant Pond, Oxford County, Pownal, Cumberland County, Norridgewock and Hartland, Somerset County, Oak Hill and Lincolnville, Waldo County, and Dedham, Hancock County, all the granite quarries of Maine are along the seaboard, either on islands or on bays or navigable rivers, or within 4 miles of them. The inland quarries are all on railroads or within a short distance of them. The distance to rail from a few quarries is 3 miles, from one 5 miles, but as the product of these quarries is used entirely for monumental work the cartage is a matter of less moment. The Maine granite industry may be said to have its center in Penobscot and Bluehill bays and the islands about them. A line drawn from Clark Island, south of Rockland, north-northeast to Frankfort, thence about east to Franklin, in Hancock County, thence southwestward through Bar Harbor, and thence around the islands southwestward back to Clark Island, would embrace an area of about 1,200 square miles, which would include the bulk of the granite industry.

Quarries of "black granite."—Of the total number of quarries, 18 are of "black granite," although a few obscure ones may have been overlooked. Their location is shown by a separate symbol on the map. They are in York, Lincoln, Waldo, Penobscot, and Washington counties. Of these only the Addison (Washington County), Vinalhaven (Knox County), and Round Pond (Lincoln County) quarries are at tidewater, but as the "black granites" are used only in small quantities for expensive work the cost of transportation is a minor consideration.

THE QUARRIES, THEIR GRANITE AND FINISHED PRODUCT.

CUMBERLAND COUNTY.

BRUNSWICK.

The Grant quarry is in the town of Brunswick, 3 miles west of Brunswick village, on the south side of the Maine Central Railroad, on the Merriman farm. It has not been operated for many years.

The granite (specimen D, XXVI, 110, a) is a biotite granite of medium-gray shade and fine, even-grained texture, in which the particles of quartz measure up to about 0.4 inch and those of feldspar and mica up to 0.15 inch. Its minerals, in descending order of abundance, are potash feldspar (both microcline and orthoclase), quartz, a feldspar with both lime and soda (oligoclase-albite), and biotite, with rarely a scale of muscovite. The orthoclase has inclusions of quartz, circular in cross section, and the second feldspar is greatly altered. Accessory: Zircon.

The opening measures about 75 by 50 feet by 5 feet in depth.

Rock structure: The sheets, 2 to 12 inches thick, dip not higher than 5°. The joints strike N. 55° W. and N. 60° E. A marked flow structure is indicated

by alternating light and dark bands, due to varying amounts of black mica, and also by the parallelism of the longer axes of the larger feldspar crystals and biotite plates. Its strike is N. 35° W. The upper sheet shows much discoloration.

Transportation, by team to railroad near by.

Product: The chapel of Bowdoin College, at Brunswick, was built of the same granite, but from another opening, referred to by George P. Merrill[83] as also furnishing the stone for the First Parish Church, in Portland.

FREEPORT.

The **Freeport quarry** is half a mile southeast of Freeport station, on the Maine Central Railroad, on the east side of a hillock 80 feet high, with northeast-southwest axis. Operator, Long & Saunders Quarries Co., Quincy, Mass. Quarry idle since 1913.

The granite specimen D, XXVII, 127, a) is a biotite-muscovite granite of medium-gray shade with a slight bluish tinge and very fine, even-grained texture, with particles ranging from 0.36 to 1.28, and, exceptionally, from 0.18 to 2.5 millimeters in diameter. Its minerals, in descending order of abundance, are potash feldspar (microcline, orthoclase), smoky quartz, soda-lime feldspar (oligoclase), black mica, and white mica. The soda-lime feldspar is considerably altered to kaolin and a white mica, and both feldspars often have intergrowths of quartz circular in cross section. The rock contains accessory apatite. It takes a fine polish. The specific gravity was reported by F. L. Bartlett, of the Maine State assay office, as 2.627. It is free from pyrite.

The quarry, first opened in 1886, measured in 1905 about 600 feet from northeast to southwest by 100 feet across, with a working face 55 feet high.

Rock structure: The granite at the northeast end of the quarry is capped by about 5 feet of schist, and in its center the excavation, in proceeding in a direction parallel to the axis of the hill, has bisected an inclusion of this same schist 3 feet thick and about 40 feet long, dipping 35° E. to a point 30 feet below the surface of the granite. This schist inclusion is described on page 63. (See also Pl. XV, *B*.) About 150 feet southeast of it is another inclusion of similar material. The presence of these inclusions necessarily involves some dead work and waste. The sheets, 1 to 8 feet thick, increasing in thickness downward, dip up to 10° SE. and 10° NW. One set of joints, strike east, spaced 20 to 50 feet, forms the northeast wall. Another set, strike N. 75° W., spaced 3 to 30 feet. The rift is horizontal and the grain vertical, striking east. A few knots, up to 12 inches across, of muscovite, quartz, and feldspar. No "sap."

Transportation, by cart half a mile to railroad or three-fourths mile to dock.

The fine texture of the stone makes it particularly well adapted for monuments. Among the monuments made of it are the Humboldt monument in Chicago and the Scott monument in Pittsburgh, Pa. The front of the Maine building at the Chicago World's Fair, afterwards removed to Poland Springs, Maine, and the polished tanks at Poland Springs also came from this quarry.

POWNAL.

The **Pownal quarry** is in the southern corner of the town of Pownal, 2½ miles north-northeast of Yarmouth Junction on the Maine Central and Grand Trunk railroads. Operator, Fred C. Greene, Freeport.

The granite (specimen D, XXVII, 123, a) is a biotite granite of light-gray shade and very fine, even-grained texture, most of the particles ranging from

[83] U. S. Nat. Mus. Proc., vol. 6, p. 171, 1883.

0.25 to 0.75 millimeter in diameter. It consists, in descending order of abundance, of very slightly smoky quartz, potash feldspar (microcline), soda-lime feldspar (oligoclase), and black mica, with accessory zircon, apatite, and magnetite. The oligoclase is much altered to a white mica, and the microcline has intergrowths of quartz, circular in cross section. The polish is inferior to that of the Freeport stone.

The quarry, opened in 1880, measured in 1905, 300 by 200 feet and averaged 3 feet in depth.

Rock structure: Flow structure at one point consists of a lamination dipping 10° E., with thin black streaks of matted biotite scales. The sheets, 4 inches to 4 feet 8 inches thick, dip 10°–15° SE. in broad undulations. They have been tested with core drills to a depth of 60 feet and the lowest sheets found to be 6 feet thick. Vertical joints, striking N. 50° E., recur every 30 or 35 feet. The rift is horizontal and the grain is vertical, striking east. A 12-inch basic dike crosses the northwest half of the quarry with a N. 50° E. course. A pegmatite dike, 4 inches thick, occurs at the west end of the quarry. There are neither knots nor rust stains nor "sap."

Transportation, by cart 2½ miles to dock or railroad.

Product, specimens: Baker mausoleum at Woodlawn Cemetery; hotel at corner of Seventieth Street and Central Park; Van Norden Trust Building, corner of Sixtieth Street and Fifth Avenue; French monument, Calvary Cemetery, New York. This quarry has not been in operation since 1915.

WESTBROOK.

Pride's quarry is in the town of Westbrook, 3½ miles northeast of Westbrook (Saccarappa) and a quarter of a mile north of Prides Corners. Operator, James H. Pride, R. D., Woodford.

The granite (specimen D, XXVII, 140, a) is biotite granite of medium-gray shade with conspicuous black mica and fine, even-grained texture (particles measuring up to 0.1 inch across), consisting, in descending order of abundance, of potash feldspar (microcline and orthoclase), smoky quartz, a little soda-lime feldspar (oligoclase), and biotite with accessory apatite. The biotite scales are generally parallel.

The quarry, opened in 1898, measured in 1905 200 by 100 feet and about 6 feet in depth.

Rock structure: There is a marked flow structure, dipping in places 30° E., which gives the granite the appearance of a gneiss. The sheets, 6 inches to 2 feet 6 inches thick, dip up to 5°. A heading on the east side strikes N. 10° E. and dips 55° W. The rift is horizontal and the grain vertical, striking east. A basic dike, 12 inches thick, striking N. 50° E., forms the west side of the quarry. Sap from 1 to 3 inches wide in upper sheets, but none 5 feet down.

Transportation: The nearest railroad is at Westbrook, 3½ miles away.

Product: Curbing and bases of monuments for local demand.

FRANKLIN COUNTY.

JAY.

The **Maine & New Hampshire Granite Corporation's quarries** are at North Jay.

The granite (specimen D, XXVII, 118, a) is a biotite-muscovite granite of very light gray shade ("North Jay white") and fine, even-grained texture, in which the particles range from 0.36 to 3 millimeters in diameter. It consists, in descending order of abundance, of potash feldspar (microcline and

orthoclase), clear quartz, soda-lime feldspar (oligoclase), black mica (biotite), and white mica (muscovite), together with accessory garnet, magnetite, and apatite. The general whiteness of this rock is due to the quartz not being smoky as in most granites, and also to the whiteness of the feldspars, which is thus visible through the quartz. The feldspars are mostly unaltered. The following chemical analysis of this granite, made by E. T. Rogers, was reported by Prof. John E. Wolff [84] in 1892.

Analysis of granite from quarry at North Jay.

Silica (SiO_2)	71.54
Titanium dioxide and Fe_2O_3 (?)	.84
Alumina (Al_2O_3)	14.24
Ferric oxide (Fe_2O_3)	.74
Ferrous oxide (FeO)	1.18
Lime (CaO)	.98
Magnesia (MgO)	.34
Soda (Na_2O)	3.39
Potash (K_2O)	4.73
Water (H_2O) at red heat	.61
Sulphur (S)	Trace.
Carbon dioxide (CO_2)	Trace.
	98.59

The same analyst finds the specific gravity 2.639. A test of the compressive strength of this granite, made for the company at the Watertown Arsenal in 1892, shows that the cube cracked at 15,720 pounds to the square inch and was destroyed at 16,310 pounds to the square inch. An earlier test of the same granite with somewhat different results was made at that arsenal on May 6, 1882.[85] It does not take a very good polish owing to the abundance of mica and the large size of its plates. The "North Jay" granite was also described by M. E. Wadsworth [86] in 1878.

The quarry, opened in 1872, consists of three openings, known as the "upper," "lower," and "boulder." The upper quarry measured in 1905 about 425 feet from north to south by 200 feet from east to west and had an average depth of 20 feet. The lower quarry, adjacent on the west, measured 500 feet from north to south and 350 feet from east to west, with an average depth of about 35 feet. These openings are on the west side of a north-south ridge. The boulder quarry, a little north of the other two, is about 150 feet square and 20 feet deep. The upper and lower quarries are separated by a mass 10 feet thick, consisting of two large aplite dikes with north-south strike.

Rock structure: In the center of the lower quarry there is a lamination in folds 20 feet broad and 3 feet high occasioned by the parallelism and abundance of biotite plates along certain planes. Some of these planes show evidence of friction along them. There is also a north-south vertical structure associated with the dikes of aplite between the two quarries. The sheets are 4 inches to 6 feet thick. In the upper 25 feet the sheets are thin, but below that they become gradually thicker. In cross-section they feather out alternately, or "toe in." (See glossary, p. 471.) At the top of the hill and at the east side of the upper quarry they are horizontal, but on the west side they curve over

[84] See U. S. Geol. Survey Nineteenth Ann. Rept., pt. 6, continued, pp. 218, 219, 1898.
[85] U. S. Geol. Survey Eighteenth Ann. Rept., pt. 5, continued, p. 961, 1897.
[86] Boston Soc. Nat. Hist. Proc., vol. 19, pp. 237–238, 1878.

westward, dipping 5°–10°, and possibly a little more in the lower quarry, governing the slope of the hill. At the north side of the lower quarry is a heading striking N. 50°–60° E., dipping 60° and also 90°. The courses of the various joint sets and dikes are shown in figure 41. Of joints (B) there are four discontinuous ones in a space of 50 feet in the upper quarry. The rift is horizontal, and there is no grain. The pegmatite dikes consist of milk-white potash feldspar (microcline) and soda-lime feldspar (oligoclase), smoky quartz, biotite, and muscovite, and measure up to 2 feet 6 inches. Knots are exceptional and measure up to 12 inches across. Heading (A) is covered with limonite from oxidation of pyrite. Rusty stain is noticeably absent from the sheets.

Transportation, by gravity track to Maine Central Railroad, 1,300 feet distant and 300 feet down.

The product is used for monuments and buildings. Specimens: General Grant's tomb, Riverside Drive, New York; Richard Smith soldiers and sailors' memorial gateway at Fairmount Park and the Penn Mutual Life Insurance Co. Building, Philadelphia; Hahnemann monument, Washington; city hall,

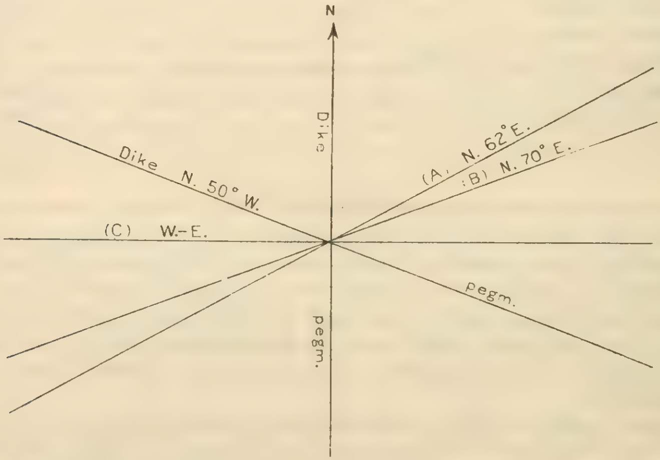

Figure 41.—Structure at Maine & New Hampshire Granite Corporation's quarry at North Jay, Maine.

Portland, Maine; Chicago & Northwestern Railway Building and Field Annex Building, Chicago; Union Trust Building, South Bend, Ind.; Exchange National Bank Building, Tulsa, Okla.

Rough stone, paving blocks, and crushed stone are important by-products.

HANCOCK COUNTY.

BLUEHILL.

The **White quarry,** in the town of Bluehill, 1¼ miles east of Bluehill village. Operator, Jesse B. Park (Inc.), 1328 Broadway, New York. Idle since 1913.

The granite (specimen D, XXVI, 36, a) is a biotite granite of medium-gray, slightly bluish color and of coarse (on the medium side) even-grained texture. The feldspars measure as much as 0.5 inch, and some of them a little more. The rock consists, in descending order of abundance, of potash feldspar (microcline and orthoclase), smoky quartz, soda-lime feldspar (oligoclase), and black mica (biotite), together with accessory zircon and magnetite. The feldspar is slightly bluish. The contrast in shade between the polished and rough sur-

face is marked, but the mica plates are sufficiently large and numerous to prevent a perfect polish. Although the texture of this stone is coarsish, it is sufficiently fine to be well adapted for fluted columns and capitals. A test of its compressive strength made at the United States Arsenal at Watertown, Mass. (test 9087, 1893) gave an ultimate strength of 29,420 pounds to the square inch under pressure applied at right angles to the rift. A similar test made by the engineering department of the School of Mines of Columbia University, in New York, gave an ultimate strength of 29,681 pounds.

The quarry, opened about 1855, measured in 1905 300 by 350 feet and from 15 to 45 feet in depth.

Rock structure: The striking geologic feature is the rectangular curved joint described on page 37 and shown in Plate XIV, *B*. The sheets, 3 to 10 feet thick, dip from 10° to 15° W. and SW. The joint courses are shown in figure 42. Joints (A) recur every 100 feet and form a heading at right of curved joint, as shown in Plate XIV, *B*. The rift is vertical, with a course N. 50° W., not very pronounced. There are small dikes and thick lenticular knots of very fine grained bluish-gray aplite. Dark-gray knots measure up to 10 by 4 inches. Sap

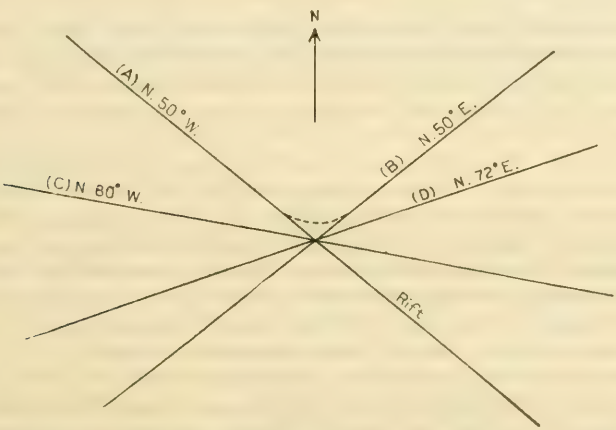

FIGURE 42.—Structure at White quarry, Bluehill, Maine. The rectangular joint is shown by the dotted line.

is confined to the upper sheets, and does not exceed 2 inches in width. There are no rust spots.

Transportation, by team to docks, one-third mile.

The product is used for buildings and monuments, and the waste goes into paving blocks. Specimens: Woman's Hospital, New York; Mercantile Trust Co. and Caledonian Insurance Co. buildings, St. Louis; basement story of District of Columbia Municipal Building; First Day and Night Bank, Delamar and Brokaw residences, New York; chemical laboratory of Pratt Institute, Brooklyn, N. Y.; chemical laboratory of Stevens Institute of Technology, Hoboken, N. J.; fountain with large monolithic bowl, Deep River, Conn.

The **Chase quarries** are in the town of Bluehill, 3 miles east of Bluehill village, and north of Woods Point. They are no longer operated.

The granite (specimen D, XXVI, 38, a) is a biotite granite of medium to light-gray color and coarse even-grained texture, the feldspar measuring up to 0.8 inch in length. It consists, in descending order of abundance, of potash feldspar (microcline and orthoclase), smoky quartz, soda-lime feldspar (oligoclase), and black mica (biotite), with accessory magnetite. The feldspars are milky

white with a slight bluish tinge. The contrasts between the feldspar, quartz, and biotite are marked, more so than in the stone of the White quarry, because the feldspar is whiter, the quartz more smoky, and the biotite a trifle coarser. The following chemical analysis of this granite, made in 1896 by Ricketts & Banks, of New York, is inserted here merely for reference:

Analysis of granite from Chase quarry, near Bluehill, Maine.

	Per cent.
Silica (SiO_2)	73.02
Ferrous oxide (FeO)	2.59
Alumina (Al_2O_3)	16.22
Manganous oxide (MnO)	Trace.
Lime (CaO)	0.94
Magnesia (MgO)	Trace.
Potash (K_2O)	3.42
Soda (Na_2O)	3.60
Sulphur (S)	None.
Loss and undetermined	0.21

The same firm also made a test of this granite (test 16606, 1899), which showed that it has an ultimate compressive strength of 23,400 pounds to the square inch.

The quarry, opened in 1872, consists of several openings on the top and eastern slopes of a hill rising 220 feet above the sea in a distance of three-fourths mile.

Rock structure: The sheets are up to 8 feet thick and are either horizontal or dip at a low angle. Vertical joints strike N. 50° W. and N. 40° E. The rift is vertical, with a north strike. There are some small dikes of aplite and dark-gray knots. Sap occurs in the upper sheets several inches thick. In one of the openings the stone has occasional light rust spots 0.5 inch in diameter, due to the oxidation of some ferruginous mineral in very minute particles.

Transportation, by cable road 1,400 feet from the main quarry to cutting shed and by locomotive track, 650 feet more, from shed to dock.

The product was used for buildings. Specimens: New York Stock Exchange, Lying-in Hospital, Manhattan Trust Building, and Grand Union Hotel, Forty-second Street, New York; the General Thomas monument and the trimmings to the Bureau of Engraving and Printing, Washington; the League Island Dry Dock; and the post office at Harrisburg, Pa.

The Chase monumental granite: About 350 feet east of the upper opening is an area about 200 feet square, of a medium bluish-gray fine-textured, porphyritic biotite-muscovite granite (specimen D, XXVI, 39, a). The particles range from 0.07 to 1.1 millimeter in diameter, averaging about 0.37 millimeter. The isolated feldspars measure up to 0.25 inch across. The minerals, in descending order of abundance, are potash feldspar (orthoclase and microcline), smoky quartz, soda-lime feldspar (oligoclase), black mica (biotite), and white mica (muscovite), with accessory magnetite. The feldspars are bluish gray. They have considerable intergrown quartz, and the rock is generally harder than the adjacent granite, which it probably traverses as a large dike. It has been quarried occasionally for local monumental use.

SOUTH BROOKSVILLE.

The **Bucks Harbor quarries** are at Bucks Harbor, South Brooksville. Operators, John T. Brady & Co., 103 Park Avenue, New York.

The granite from an opening half a mile southeast of South Brooksville, (specimen D, XXVI, 46, a) is a biotite granite of light grayish-buff color with

conspicuous black mica, and is of coarse, inclining to medium, even-grained texture. It consists, in descending order of abundance, of a light cream-colored potash feldspar (microcline and orthoclase), smoky quartz, a milk-white soda-lime feldspar (oligoclase), and black mica (biotite), with accessory magnetite. The oligoclase is partly altered to kaolin and a white mica. A little pyrite was found at the quarry.

The granite from an opening one-fourth mile northeast of South Brooksville (specimen D, XXVI, 47, a) is a biotite granite of medium-gray shade, with conspicuous black mica, and coarse, even-grained texture. It consists, in descending order of abundance, of a very light gray potash feldspar (microcline and orthoclase), slightly smoky quartz, a little soda-lime feldspar (oligoclase), and black mica (biotite).

Both of these granites are bright from the contrasts of their minerals.

The quarries consist chiefly of two openings, one lying half a mile southeast of the village measured in 1905 200 feet by 100 feet and 5 to 20 feet in depth; the other, one-fourth mile northeast of the village, was about 200 by 100 feet and from 5 to 10 feet deep.

Rock structure: The sheets at these quarries, 2 to 8 feet thick, are either horizontal or dip 10°–15° W. Joints at the first opening strike N. 40° W., dip 75° SW., and recur at intervals of 15 feet or more; also NE., dipping 75° S. 40° W. to 90°. The rift is vertical, striking N. 30° E. The sap is confined to the uppermost sheets.

Transportation: The company owns two granite wharves, which afford 12 feet of water at low tide.

The quarries were idle in 1917.

DEDHAM.

The **Brown quarry** is in the town of Dedham, 1½ miles east of Holden station (East Holden post office) on the Maine Central Railroad, on the northeast side of a hill 840 feet above sea level and having a northwest-southeast axis. Operator, William J. Brown, East Holden. Idle since 1913.

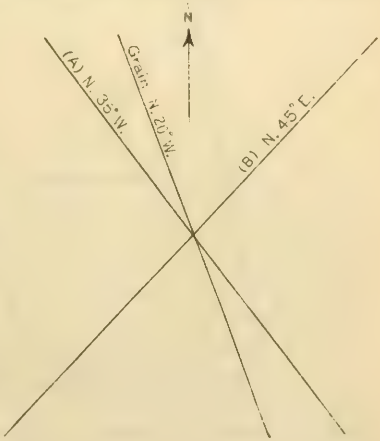

FIGURE 43.—Structure at Brown quarry, Dedham, Maine.

The granite (specimen D, XXVI, 108, a) is a biotite granite of dark-gray matrix with light-grayish feldspars and of very coarse porphyritic texture, with some evidence of distortion and crushing of its feldspars. These measure up to 1.5 inches in diameter, and the black mica up to 0.3 inch. The feldspars are generally twinned and in places of oval or roundish outline. The rock consists, in descending order of abundance, of potash feldspar (orthoclase and microcline), smoky quartz, soda-lime feldspar (oligoclase), and black mica (biotite), together with accessory zircon, apatite, and secondary magnetite and chlorite. The quartz contains needles of rutile(?). The orthoclase crystals contain zonally arranged quartz grains and biotite scales, and some of them are thinly rimmed with oligoclase or intergrown with it. Many small grains of quartz in the matrix indicate crushing. The oligoclase is partly altered to kaolin and a white mica.

The rock takes a fine polish, but the durability of the polish under outdoor exposure is doubtful, owing to the large size of the mica scales.

Rock structure: The sheets, 2 to 6 feet thick, dip 15° SSE. Joint courses are given in figure 43. Joints (A) recur at intervals of 100 to 200 feet; (B) at intervals of 75 feet or more. The rift is horizontal. Aplite dikes, 1 to 4 inches thick, cross the grain at a high angle. No knots are in sight. Sap, 1 to 2 inches thick, is confined to the topmost sheet.

Transportation, by cart 1½ miles to cutting shed at Holden station.

The product was used for bridge work.

FRANKLIN.

The **Robertson quarry** is in the town of Franklin. Operator, Harvey E. Robertson, North Sullivan.

The granite (specimen D, XXVI, 71. a) is a biotite granite of medium-gray shade and of coarse, inclining to medium, even-grained texture, with whitish feldspars up to 0.5 inch in diameter. Its constituents, in descending order of abundance, are potash feldspar (orthoclase and microcline), slightly smoky quartz, soda-lime feldspar (oligoclase), and black mica (biotite), with accessory magnetite and pyrite. The slight contrast between the shade of the quartz and that of the feldspar and the small size of the biotite scales produce a general lack of brilliancy in the rock.

The quarry, opened in 1892, measured in 1905 300 feet from north to south by 300 feet from east to west and 5 to 15 feet in depth. It is drained by two siphons 800 and 1,000 feet long.

Rock structure: The sheets, 2 to 8 feet thick, are mainly horizontal but on the west side dip 10° W. The courses of joints and dikes are given in figure 44.

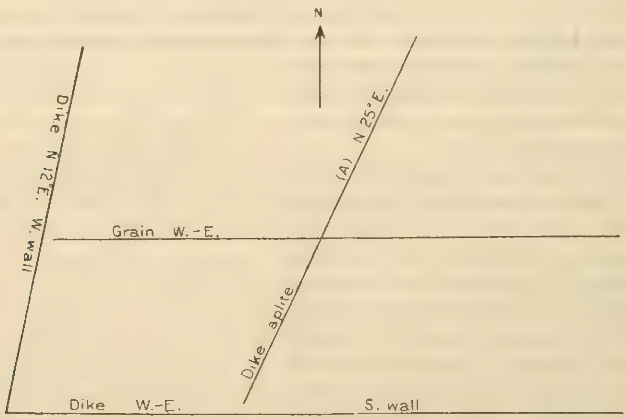

FIGURE 44.—Structure at Robertson quarry, Franklin, Maine.

Joints (A) recur at irregular intervals. The rift is horizontal, and the grain is vertical, striking east-west. Aplite dikes are 2 to 8 inches thick, and the granite for about a foot on each side of them is close jointed. Knots are rather abundant and up to 2 feet across. The north-south joint face carries some pyrite. Sap is 2 to 3 inches thick along the sheets. No rust spots were detected. A 1-foot diabase dike, with its rim altered to epidote, forms the west wall of the quarry, and a 2½ to 3 foot dike forms the south wall. For a space of 10 feet on each side of this dike the shade of the granite has been changed to a dark gray, and the rock is filled with close joints of low dip. The microscope shows that

the quartz particles and some of the feldspars are crossed by more or less parallel cracks, from 0.25 to 1.25 millimeters apart.

Transportation, by cart 1¾ miles to dock in bay.

The product is used for curbing, both straight and circular, and for paving blocks and "random" stone.

The **Bragdon quarry** is in the town of Franklin. Operator, L. C. Bragdon, Franklin. Idle since 1919.

The granite is a biotite granite of medium-gray shade and medium, even-grained texture like that of the Crabtree & Havey quarry (specimen D, XXVI, 69, a), in Sullivan (p. 219). Molybdenite was found in it.

The quarry measured in 1905 300 feet from north to south by 150 feet from east to west and 10 to 20 feet in depth and is drained by a siphon pipe.

Rock structure: The sheets, 2 to 6 feet thick, dip 10°–15° W. Joints strike N. 12° E. and are spaced 150 feet. A 6-inch basic dike striking N. 12° E. forms the west wall. Another, a foot thick, strikes almost due east.

Transportation, by cart 2 miles to wharf.

The product is used for curbing (both straight and circular), paving blocks, and "random" stone.

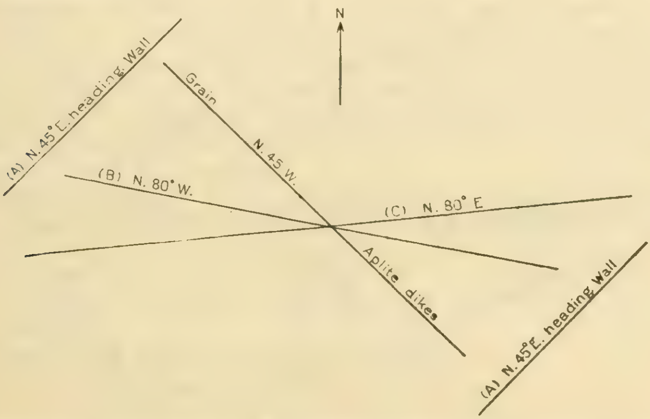

FIGURE 45.—Structure at T. M. Blaisdell quarry, East Franklin, Maine.

The **T. M. Blaisdell quarry** is in East Franklin, 1 mile above the head of navigation. Operator, T. M. Blaisdell, East Franklin.

The granite (specimen D, XXVI, 76, a) is a biotite granite of a medium to dark gray shade and medium even-grained texture, with feldspars up to 0.25 inch in length. It consists, in descending order of abundance, of potash feldspar (microcline and orthclase), slightly smoky quartz, lime-soda feldspar (oligoclase to oligoclase-albite), black mica (biotite), together with accessory magnetite and zircon. The effect of the slightly bluish-gray color of the feldspar and the light smokiness of the quartz is to prevent any contrast of shade between these two minerals and also to darken the general color of the stone.

The quarry, opened about 1875, measured in 1905 200 by 300 feet and was of varying depth. The working face on the north was 53 feet high.

Rock structure: The sheets, from 2 to 13 feet thick, dip 10° NE. Owing to compressive strain, on the removal of load in quarrying, the bottom sheet rises half an inch from the underlying one. The joint courses are shown in figure 45. (A) forms a heading on the northwest and southeast sides. (C) dips in places 45° N. The rift is horizontal, and the grain vertical, striking

northwest. Several parallel dikes of aplite up to 2 inches thick dip southwest at a low angle. In one 5-foot mass there are five of these. Sap is confined to the upper sheets. Black knots up to 8 inches across.

Transportation, by cart a few hundred feet, thence by lighter a mile to schooners.

The product is used for curbing. paving, bridges, docks, and "random."

The **W. B. Blaisdell quarry** is in the town of Franklin, on the southeast side of Sullivan River. Operators, W. B. Blaisdell & Co., Franklin.

The granite (specimen D, XXVI, 78, b) is a biotite granite of medium-gray shade and medium, inclining to coarse, even-grained texture. It consists, in descending order of abundance, of potash feldspar (microcline and orthoclase), smoky quartz, soda-lime feldspar (oligoclase), and black mica (biotite), together with accessory magnetite. zircon, apatite, and secondary epidote and chlorite. The oligoclase is partly altered to a white mica. The feldspars are grayish and are therefore of almost the same shade as the quartz, which deprives the rock of marked contrasts. It is a little lighter than the specimen 76, a, of the T. M. Blaisdell quarry, and is said to be a little softer. E. C.

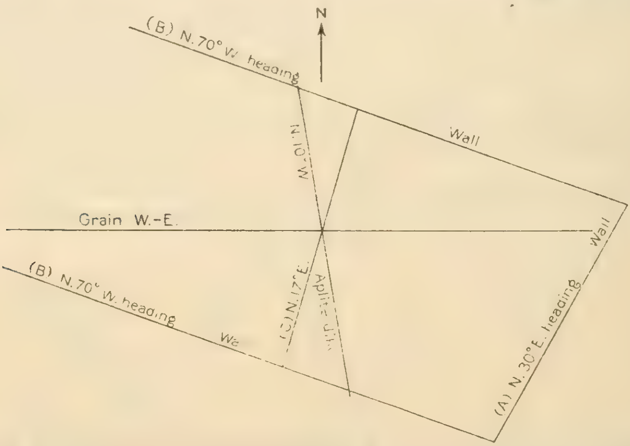

FIGURE 46.—Structure at W. B. Blaisdell quarry, East Franklin, Maine.

Sullivan, of this Survey, has tested the granite with warm dilute acetic acid and finds that it contains 0.15 per cent of CaO (lime), much MgO (magnesia), and 0.104 per cent of CO_2 (carbon dioxide). If all the CO_2 were allotted to CaO it would give 0.24 per cent of $CaCO_3$ (calcium carbonate) as the content in the granite.

The quarry, opened about 1875, measured in 1905 300 by 250 feet and 15 to 35 feet in depth.

Rock structure: The sheets, 6 to 7 feet thick, generally dip northwest at low angles. There is some "toeing in," owing to the overlapping of lenses. Joint and vein courses are given in figure 46. (A) forms a heading on the east side of quarry; (B) is on the north and south sides and is coated with calcium carbonate (calcite), as described on page 39. The heading on the south has four joints 3 feet apart. (C) is coated with pyrite. The rift is horizontal, and the grain vertical eastward. The sap is from 1 to 3 inches thick. There are some knots up to 6 inches across.

Transportation, by "lifters" drawn by horses 1,000 feet to schooners at dock.

The product is used for curbing (both straight and circular) and paving.

The **Bianchi quarry** lies between Mill Pond and Great Pond roads in West Franklin. Owner, Emerald Granite Co. (Stephen Bianchi), 46 Cornhill, Boston. Idle in 1921 and 1922.

The granite (specimen D, XXXVIII, 25, a), "Emerald granite," is an altered (saussuritized) gabbro (determination by E. S. Larsen, of this Survey) of very dark greenish-gray color. It consists of a plagioclase feldspar near labradorite and of hornblende after pyroxene with very little pyrite. It takes a high polish. The polished face is black, irregularly speckled with pale blue-greenish gray, and cuts almost white.

This "black granite" is very suitable for inscribed monuments.

The **Bradbury quarry** is in West Franklin, near the north end of Grape Pond. Operators, F. Bradbury & Sons, West Franklin.

The granite (specimen D, XXVI, 77, a) is biotite granite of dark-grayish, slightly purplish color and of very coarse, somewhat porphyritic texture, with feldspars up to an inch in diameter and black mica plates up to 0.1 inch. It consists, in descending order of abundance, of a grayish-purplish potash feldspar (orthoclase and microcline), smoky quartz, yellowish-white soda-lime feldspar (basic oligoclase), and black mica (biotite), together with accessory magnetite, apatite, zircon, and secondary chlorite. Many of the grayish-purplish potash feldspars are rimmed with the yellowish oligoclase and are also intergrown microscopically with a plagioclase feldspar and with quartz. This granite is very striking in the contrasts of its minerals. Its quartz and feldspars take a high polish, but the large biotite scales are not favorable to the durability of the polish under outdoor exposure.

The quarry is triangular in area, each side of the triangle measuring in 1905 about 75 feet, and its depth in places 15 feet, which is the height of the working face.

Rock structure: The sheets, 10 feet thick, are about horizontal. Joints striking N. 70° W. and dipping high recur at intervals of 5 feet or more. There are a few knots.

Transportation, by cart to railroad about 900 feet.

The product has been used for railroad culverts.

LONG ISLAND (BLACK ISLAND).

The **Black Island quarries** are in the northeastern part of Black Island, which lies south of Mount Desert, in the town of Long Island. Operator, in 1905, Black Island Granite Co., New York.

The quarries, opened in 1892, consist of two openings. The upper one, about one-fourth mile south of the dock at the northeast corner of the island, measures 500 by 300 feet and from 10 to 40 feet in depth; the lower one, known as the "Redcliff," a little south of the dock, is about 100 feet square.

Specimen D, XXVI, 31, a, from the upper quarry, is a biotite granite of light pinkish-gray color and medium, inclining to coarse, even-grained texture. It consists, in descending order of abundance, of potash feldspar (microcline and orthoclase), smoky quartz, soda-lime feldspar (oligoclase), and very little black mica (biotite), together with accessory titanite and magnetite. Both feldspars are light pink. Some of the potash feldspar is rimmed with oligoclase, which in places is part altered to kaolin and a white mica. The rock presents but faint contrasts of color and, owing to the small quantity of its mica, must needs take a very fine polish.

The granite (specimen D, XXVI, 39, a), "Redcliff," of the lower quarry is a biotite granite of medium pinkish-gray color and medium, inclining to coarse, even-grained texture. It consists, in descending order of abundance, of potash feldspar (microcline and orthoclase), smoky quartz, soda-lime feldspar (oligo-

clase), and very little black mica (biotite), together with accessory titanite, magnetite, and zircon. Both feldspars are pinkish. The oligoclase is largely altered to kaolin and a white mica. Its small content of mica must make this granite suspectible of high polish.

Rock structure: At the upper quarry the sheets, 8 inches to 5 feet thick, are horizontal, with minor undulations. Vertical joints strike N. 70° W., and recur at intervals of 100, 200, and 250 feet. The rift is parallel to these, but feeble. Sap, 3 inches thick, is confined entirely to the upper sheets. At the Redcliff quarry the sheets, up to 6 feet thick, bend over from the horizontal to 25° N. and NE. Vertical joints strike N. 77° E., recur at intervals of 50 feet. Another set, strike N. 35° E., abounds at the sides of the quarry but is scarce in the center. Joints of this strike are numerous along the north shore of the island. The rift is vertical, with a N. 77° E. course.

The product of the upper quarry was used for buildings, and its thin sheets for paving. That of the Redcliff quarry was used for monuments and columns. Specimen: Park Building, Brooklyn, N. Y.

The quarries are now abandoned.

MOUNT DESERT.

The **Hall or McMullen quarry** is in the town of Mount Desert, southeast of the village of "Hall Quarry" and four-fifths mile north of the Robinson Mountains. Operator, Booth Bros. & Hurricane Isle Granite Co., 208 Broadway, New York.

The granite (specimen D, XXVI, 55, aa) is a biotite granite of general light-buff grayish color and coarse, inclining to medium, even-grained texture. It

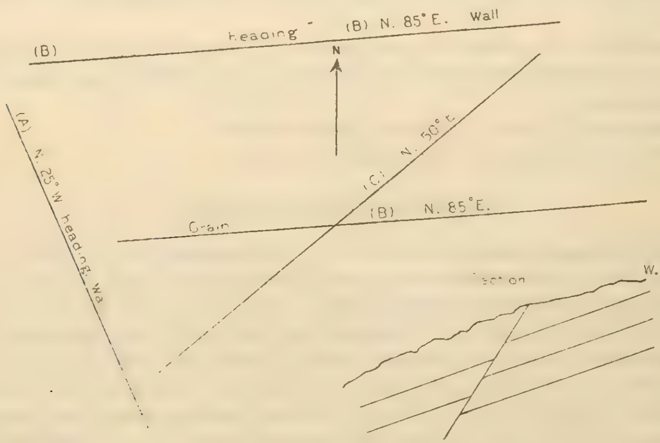

FIGURE 47.—Structure at McMullen quarry, Mount Desert Island, Maine. The section shows the "toeing in" of sheets, probably by faulting along the joints.

consists, in descending order of abundance, of buff potash feldspar (orthoclase intergrown with plagioclase), smoky quartz, milk-white soda-lime feldspar (oligoclase), and black mica (biotite), together with accessory apatite and a little secondary calcite within the oligoclase. The contrasts resulting from the different colors of the four minerals are attractive and must come out still more strongly on the polished surface. E. C. Sullivan, of this Survey, finds that it contains 0.014 per cent of CO_2 (carbon dioxide) and that warm dilute acetic acid dissolves traces, of CaO (lime) and MgO (magnesia). This per-

centage of CO_2, if all allotted to CaO, would imply the presence of 0.03 per cent of $CaCO_3$ (calcium carbonate). The microscope also shows the presence of a carbonate in very minute quantity.

The quarry, opened about 1880, measured in 1905 250 feet from north to south by 250 feet from east to west and was 50 feet deep at the west side.

Rock structure: The sheets, 2 to 12 feet thick, dip 5°–10° N., S., and E. They are faulted along some of the N. 25° W. joints, resulting in a toeing in of the sheets, which necessitates quarrying from west to east—that is, toward the hade of the faults, as shown in figure 47. The courses of the joints are shown in the same figure. (A) forms a heading on the west, dip 80° W.; (B), dip, 65° S., forms a heading on the north and recurs at middle of quarry; (C), dip 75°–80°NW., forms a heading on the south and recurs at irregular intervals. The rift is horizontal and the grain strikes about east. Sap along some of the sheets is 3 inches thick and exceptionally 18 inches. The granite along joints (A) and (B) for the space of a foot is bright reddish. (See p. 81.) The faces are greenish, probably from chlorite and epidote. Dark-gray knots measure up to 6 inches in diameter.

Transportation, by track 800 feet to wharf, which is accessible to schooners of 20 feet draft.

Product specimens: United States mint, Philadelphia; basement of New York customhouse; Brooklyn anchorage to Manhattan Bridge; and bridge over the Potomac at Washington.

The **Campbell & Macomber quarry** is in the town of Mount Desert, half a mile north of the top of Robinson Mountain, at its foot, and two-fifths of a mile south of Hall Quarry village. This quarry is owned by Hale & Hamlin, of Ellsworth, Maine, but is no longer operated.

The granite (specimen D, XXVI, 56 a), "Somes Sound pink," is a biotite granite of light pinkish-gray color and medium, inclining to coarse, even-grained texture. It consists, in descending order of abundance, of a delicate pink potash feldspar (orthoclase, with very little microcline), smoky quartz, milk-white soda-lime feldspar (oligoclase), and black mica (biotite), together with accessory magnetite, zircon, and apatite. It takes a fine polish. This stone differs from that of the McMullen quarry in the tint of its orthoclase.

The quarry, opened about 1880, measured in 1905 150 by 200 feet by 20 feet in depth.

Rock structure: The sheets, 2 to 6 feet thick, dip 10°–15° E. and exceptionally are thinner at the bottom than at the top of the quarry. The joints strike east, N. 12° E., and N. 52° E. The rift is horizontal, and the grain N. 75° E. A diabase dike, 2½ feet wide, strikes N. 20° W. at the west side of the quarry. This is described on page 52. There are a few knots, but no sap.

Transportation, by cart 1,600 feet to wharf on Somes Sound.

Specimen buildings: Crocker residence, Darlington, N. J.; Danforth Library, Paterson, N. J.; First National Bank, Baltimore, Md.; Phœnix National Bank, Hartford, Conn.

The **Snowflake quarry** is on Mount Desert, about a quarter of a mile northwest of Hall Quarry village. Operator, Allen Granite Co., Mount Desert. Quarry abandoned.

The granite (specimen D, XXVI, 58, a) is a biotite granite of medium-gray shade and fine texture, with porphyritic pinkish feldspars up to 0.4 inch in diameter. It consists, in descending order of abundance, of pinkish potash feldspar (orthoclase), smoky quartz, white translucent soda-lime feldspar (oligoclase), and black mica (biotite), together with accessory magnetite. The orthoclase is intergrown with a plagioclase.

The quarry was in 1905 about 200 feet square and 5 to 10 feet deep.

Rock structure: The sheets, 6 inches to 3 feet thick, are horizontal. Joints forming a heading on the east side strike N. 20° W. and dip 75° W. A diabase dike, 6 to 10 inches thick, with course N. 20° W., traverses the entire quarry.

The product is confined to paving blocks, which are carted about half a mile to the wharf.

The **Allen quarry,** of the same concern as the Snowflake quarry, lies a quarter of a mile east of it. The granite closely resembles that of the Snowflake. The sheets are 6 inches to 3 feet thick. Plate XVI, *B*, shows the sheets crossed by a diabase dike, which has a N. 15° W. course and is faulted in two directions. (See p. 51.) There are geodes of pink feldspar, quartz, and epidote.

The **Graves Bros. quarry** is on Mount Desert, in the northern part of the village of Northeast Harbor; address, Northeast Harbor. This quarry is worked only occasionally, for underpinning. It is mentioned here on account of the exceptional character of the stone among Maine granites. This granite (specimen D, XXVI, 64, a) is a hornblende granite of general dark-gray shade and medium even-grained texture, consisting, in descending order of abundance, of greenish-gray and pinkish potash feldspar (orthoclase and microcline), with intergrown soda-lime feldspar (oligoclase-andesine), smoky quartz, and dark-green hornblende, together with accessory magnetite, apatite, and secondary chlorite. The feldspar is largely altered to a white mica. A similar granite occurs also 1½ miles west-northwest of it, at the Carroll quarry, in the town of Tremont, at the south foot of Dog Mountain. (See p. 233.)

The quarry measured in 1905 100 by 50 feet and 10 feet in depth. The sheets are up to 6 feet thick and dip 5°–10° W. There is much discoloration.

STONINGTON DISTRICT.

DISTRIBUTION AND GEOLOGY OF THE QUARRIES.

The granite industry which centers in Stonington is distributed over an area of about 4 miles square. (See map, fig. 48.) Some of the quarries are on Deer Isle, others are south of it, on Crotch Island, so named from the inlet which divides it, and the rest are on neighboring islets.

The southern half of Crotch Island, which measures about 1,500 feet from north to south, shows sheet structure very clearly. (See Pl. X, *B*.) The sheets slope northwest and southeast at angles of 10°, 15°, 20°, and 25° from its central part (140 feet above sea level), where they are horizontal. The east-west vertical joints are conspicuous from a distance. The Goss quarry has cut into the center of the arch and also on either side of it, while the Ryan-Parker quarry (Pl. XI, *A*) on the south is on the southeast slope of the sheets and of the hill. In the northern half of Crotch Island, at the lower quarry of the Sherwood Co., the coarse granites are in contact with a fine-textured one, which is also exploited. The contact line is vertical, but the sheets traverse both granites indifferently. The Stonington quarries embrace several varieties of granite.

QUARRIES.

The **Ryan-Parker quarry** is on Crotch Island, in its southeastern part, at Thurlow Head. (See fig. 48.) Operator, Crotch Island Granite Co., Grand Central Terminal, New York. Idle since 1916.

The granite (specimen D, XXVI, 20, a), "Crotch Island," is a biotite granite of lavender-tinted medium-gray color and coarse, even-grained texture. It consists, in descending order of abundance, of very light lavender-colored potash feldspar (orthoclase and microcline), smoky quartz, milk-white soda-lime feldspar (oligoclase), and a little mica (biotite), rarely a plate of musco-

vite, together with accessory magnetite, titanite, zircon, and pyrite, partly altered to limonite. The potash feldspars measure up to 1 inch, and many of them are twinned and intergrown with a plagioclase. The biotite plates do not exceed 0.1 inch across. The oligoclase is generally much altered to a white mica and kaolin and forms rims about many of the pale lavender orthoclase crystals.

E. C. Sullivan, of this Survey, determined the presence of 0.44 per cent of CO_2 (carbon dioxide) and of 0.08 per cent of CaO (lime) and a little MgO

FIGURE 48.—Map showing location of quarries about Stonington, Maine. (Reduced from topographic map of Deer Isle quadrangle, U. S. Geol. Survey.)

(magnesia) extractable with dilute acetic acid. To allot all the CO_2 to the CaO would give 0.10 per cent of calcium carbonate in the granite.

This is a very handsome granite. It is coarse-textured and is therefore largely used for massive construction. Its polished surface is attractive on account of the contrasts between pale lavender, white, and black particles, and it is therefore in demand for base courses and wainscoting.

The quarry, opened about 1880, measured in 1905 about 700 by 300 feet, and from 20 to 75 feet in depth, averaging about 35 feet. (See Pl. XI, *A*.)

Rock structure: The sheets vary and increase in thickness downward and dip 20°–25° SE. Joint courses are shown in figure 49. (A) dips 80° and forms

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a heading on the north, and (B) also forms one. Both (A) and (B) are infrequent. The rift is vertical and trends N. 60° W. Sap is 6 to 12 inches thick on either side of joint (B).

Transportation to wharves is by means of gravity on tracks 75 and 100 feet long.

The product is used chiefly for massive construction and for buildings. Specimens: Piers of Blackwells Island Bridge and retaining wall of Riverside Drive, New York.

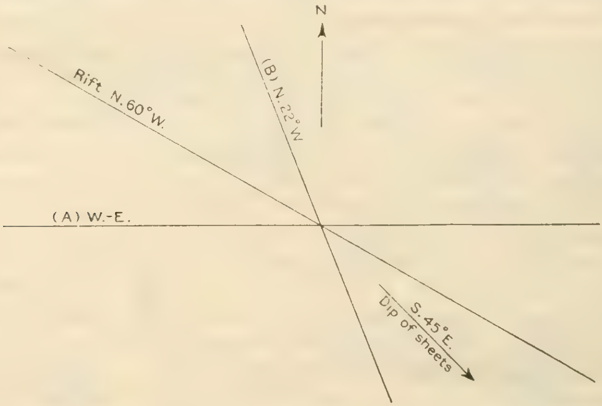

FIGURE 49.—Structure at Ryan-Parker quarry, Crotch Island, Maine.

The **Goss quarry** is on Crotch Island, adjacent to and north of the Ryan-Parker quarry, on Thurlow Head. (See fig. 48 and Pl. X, *B*.) Operator, John L. Goss Corporation, Stonington.

The granite is a biotite granite, identical with that of the Ryan-Parker quarry (specimen 20, a), described on page 224.

The quarry, opened about 1872, measured in 1905 about 350 feet square, with a maximum depth of 120 feet and a minimum of 10 feet.

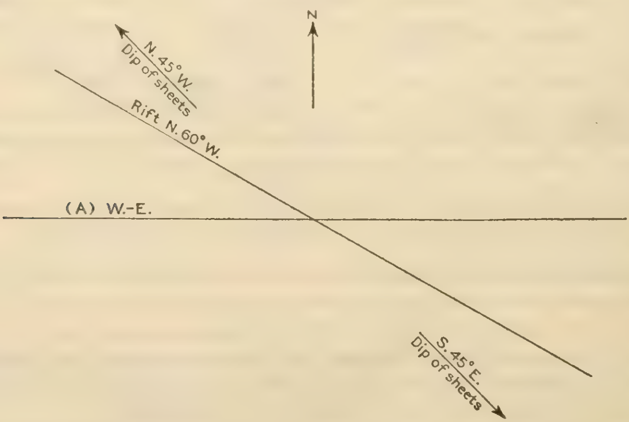

FIGURE 50.—Structure at Goss quarry, Crotch Island, Maine.

Rock structure: The sheets, 1 to 30 feet thick, increase rapidly in thickness downward. They are horizontal in the center of the quarry, but south of it dip up to 20° SE. and north of it as steeply to the northwest. The joint courses and rift are shown in figure 50. Of (A) there are only two or three in the quarry. Their faces are coated with epidote. There is no sap.

Transportation, by three tracks—one 100, one 400, and one 500 feet long—from quarry to dock; cars propelled by cable engines.

The product is used chiefly for bridges and buildings. The small beds are worked into paving blocks.

Specimens: Post office, Lowell, Mass.; courthouse, Dedham, Mass.; Merchants National Bank, New Bedford, Mass.; Larz Anderson Bridge, Cambridge, Mass.; picture gallery of Museum of Fine Arts, Boston; Pilgrim Monument, Provincetown, Mass.; public library, Laconia, N. H.; Ninth Regiment Armory, trimmings of University Heights Bridge, New York; Rockefeller fountain, Pocantico Hills, N. Y.; National Security Bank, Los Angeles, Calif.

The **Benvenue quarry** was opened by the Benvenue Granite Co. in 1906 on the west side of Crotch Island, but the company went out of business in 1915. The granite is identical with that of the Ryan-Parker and Goss quarries.

The **Sherwood quarries** are north of Mill Cove, Crotch Island. Operator, S. Clinton Sherwood, 14 Wall Street, New York. (See fig. 48 for location of quarries.) Idle since 1907.

The granite of the lower and northern quarry (specimen D, XXVI, 25, a) is a biotite-muscovite granite of light-gray shade, with a very slight buff

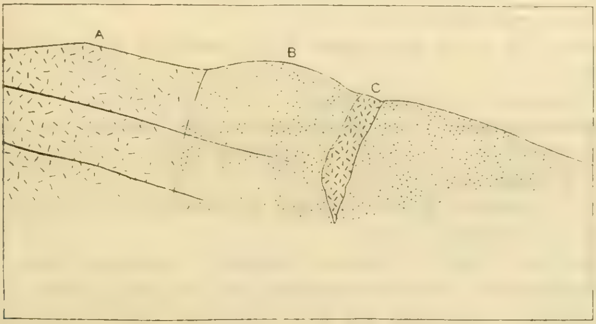

FIGURE 51.—Relations of fine biotite-muscovite granite (B) to coarse biotite granite (A and C) and of sheet structure to both at north end of Sherwood lower quarry, Crotch Island, Maine. Length, 9 feet.

tinge, and of very fine texture, most of its particles ranging in size from 0.11 to 1.1 millimeters, the average diameter being about 0.45 millimeter. There are, however, a few quartz particles and feldspar crystals 0.25 inch across, and of the latter rarely 0.5 inch in length, so that the rock has a porphyritic texture. The constituents, arranged in descending order of abundance, are potash feldspar (microcline and orthoclase), smoky quartz, soda-lime feldspar (oligoclase), black mica (biotite), and white mica (muscovite), together with accessory magnetite and secondary epidote. The oligoclase is largely altered to a white mica and kaolin, and all the feldspars are in places intergrown with quartz circular in cross section.

The lower quarry, opened in 1889, is triangular in area; in 1905 each side was 75 feet long and 40 feet deep, two of them working faces.

Rock structure: The sheets, 2 to 8 feet thick, dip 5°–10° W. Joints, dipping 70° S. to 90° and striking N. 75° E., recur at intervals of 1 to 10 feet. The rift is vertical, with strike N. 60° W., as at the south quarries of the cove. The relations of this fine granite at the north end of the quarry to the coarse

granite of the island are shown in figure 51. The fine granite probably represents a later eruption through the coarser. (See p. 34.)

Transportation, by track 100 feet to wharf.

This quarry is worked only on special orders.

The product is used for monuments, bases, etc.

The granite of the same firm's upper quarry, opened in 1890 (specimen D, XXVI, 26, b), is a biotite granite of general pinkish-buff color and coarse even-grained texture, consisting of pinkish-buff potash feldspar, smoky quartz, cream-colored soda-lime feldspar, and black mica. The potash feldspar measures up to an inch or more in length, and the biotite scales 0.1 inch. This stone appears to be identical with that of the Latty quarry on Green Isle (specimen D, XXVI, 28, a).

The upper quarry in 1905 was 200 by 100 feet and averaged about 15 feet in depth.

Rock structure: The sheets, 1 to 5 feet thick, dip 5°–10° E. and W. Vertical joints strike N. 50°–60° W. and parallel to the rift. For a space of 50 feet across the middle of the quarry these recur at intervals of 2 to 8 feet. Another set, less numerous, strike N. 25° W. and dip 60° E. There is an irregular tapering dike of pegmatite, with pink and white feldspar, biotite, and muscovite. The sheets in the upper part of the quarry have "shakes" for 2 to 3 inches from their surface.

Transportation, by cable and engine along 900-foot track to dock on east side of island.

The product consists of random stone.

The **St. Helena quarry** is on St. Helena Island (see map, fig. 48) 2 miles southeast of Stonington. Operators, Benisch Bros., 895 Jamaica Avenue, Brooklyn, N. Y. Idle since 1917.

The granite is reported by the operator as like that of the Goss quarry on Crotch Island, described on p. 226.

Product, specimen: Marine wireless operators' monument, New York.

The **Latty quarry** is in the southeastern part of Green Island, 1 mile southeast of Stonington. (See map fig. 48.) Operator, Latty Bros. Granite Co., Stonington. Quarry abandoned.

The granite (specimen D, XXVI, 28, a) is a biotite granite of pinkish-buff color and coarse, even-grained texture, consisting of a pinkish-buff potash feldspar, smoky quartz, cream-colored soda-lime feldspar, and black mica. The potash feldspar measures up to an inch, and the biotite up to 0.15 inch in diameter. The stone appears to be identical with that of the upper quarry of the Sherwood Co., on Crotch Island.

Rock structure: The sheets, 6 feet to 6 feet 8 inches thick, dip gently southeast. There are vertical joints striking N. 45° W., spaced 6 to 12 feet, also forming a heading. The rift is vertical, with course N. 60° W.

The quarry was opened in the spring of 1905.

Transportation, by a 100-foot track to wharf.

The **Stonington quarry** is on the west shore of Spruce Island, 3¼ miles east-southeast of Stonington. (See map, fig. 48.) Quarry opened in 1905, now abandoned.

The granite (specimen D, XXVI, 27, a) is a biotite granite of pinkish-buff color and very coarse, semiporphyritic texture. It consists of a pinkish-buff potash feldspar in crystals measuring up to 1.25 inches in diameter, smoky quartz, cream-colored soda-lime feldspar (oligoclase) in particles and crystals up to

0.5 inch in diameter, and black mica in scales measuring up to 0.15 inch across. The contrasts between the two feldspars and the mica are strong. The smoky quartz is a little darker than the potash feldspar. Some of the pinkish-buff feldspar is rimmed with the cream-colored one.

Rock structure: The sheets, 5 to 8 feet thick, dip about 40° W. Vertical joints strike N. 45° E., N. 45° W., and N. 80° E.

The **Moose Island quarry** is in the southeastern part of Moose Island, three-fourths mile west-southwest of Stonington. (See map, fig. 48.) Operator, John L. Goss Corporation, Stonington.

The granite is a biotite granite identical with that of the Goss and Ryan-Parker quarries on Crotch Island (specimen D, XXVI, 20, a), described on page 224.

The quarry, opened in 1873, measured in 1905 600 by 200 feet and averaged about 17 feet in depth.

Rock structure: The sheets, 1 to 7 feet thick, dip 5°–10° E. Vertical joints, strike N. 80°–85° W., recur at intervals of 200 feet and form a heading on north side of quarry. There is no perceptible rift, and the rock does not split well

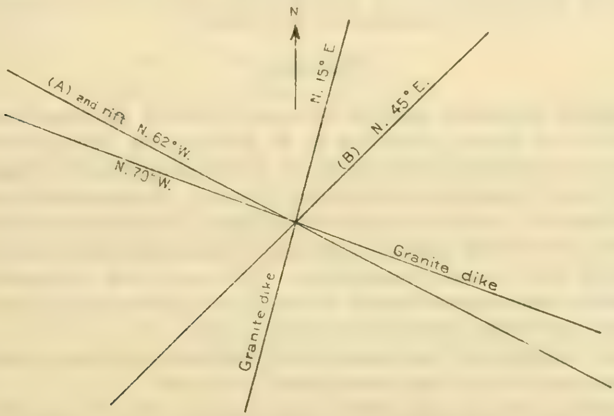

FIGURE 52.—Structure at Settlement quarry, on Deer Isle, near Stonington, Maine.

when frozen. The 15-inch aplite vein, described on page 43, has a N. 80° W. course. Sap, 1 to 2 inches thick, is confined to the upper sheets.

Transportation, by track 200 feet to wharf.

Specimen structures: Gate house at Central Park and steps of Columbia University, New York; trimmings of Hampton Dormitory, Cambridge, Mass.

The **Settlement quarry** is on Deer Isle, on Settlement Hill east of Webb Cove, 2 miles northeast of Stonington. (See map, fig. 48.) Owner, Rodgers Granite Corporation, 271 West One hundred and twenty-fifth Street, New York.

The granite (specimen D, XXVI, 22, a) is a biotite granite of medium-gray, slightly lavender tint, blotched with cream white, and of coarse texture. It consists, in descending order of abundance, of a very light lavender-colored potash feldspar (microcline and orthoclase), smoky quartz, slightly cream-colored soda-lime feldspar (oligoclase), and black mica (biotite), together with accessory magnetite, titanite, and apatite and secondary chlorite. Some of the potash feldspar is rimmed with oligoclase. The feldspars measure up to 1 inch, and the biotite plates are under 0.1 inch. The contrast between the two feldspars and the mica is strong, but that between the quartz and the potash feldspar is feeble.

The quarry, opened in 1900, consisted in 1905 of two quarries—one near the top of the hill, 500 by 400 feet and 10 to 18 feet in depth; the other, on its west side, 600 by 60 feet and up to 14 feet in depth.

Rock structure: The sheets, 6 inches to 16 feet thick, dip 10°–15° N. and S., away from the top of the hill. Joint courses are shown in figure 52. (A) occurs but once; (B) recurs at intervals of 500 feet. The rift is vertical, with a course of N. 60°–65° W. There are granite dikes 4 to 12 inches thick. (See description on p. 41.) Knots are rare and small. Pyrite occurs very rarely.

Transportation, by locomotive and 2,500 feet of track. The distance from upper quarry to cutting shed is 1,000 feet, and from cutting shed to wharf is 600 feet.

The product is used for massive construction. Specimens: Dry dock, Norfolk, Va.; base and approach for addition to Bancroft Hall, United States Naval Academy, Annapolis, Md.; fish pier, Boston; sea wall, Providence, R. I.; retaining wall, Riverside Drive (One hundred and thirty-eighth Street to end); Brooklyn and Manhattan approaches and piers to Manhattan bridge, New York. Quarry now leased to Geo. A. Fuller Co., New York, and supplying part of the stone for the new courthouse in New York.

SULLIVAN.

The **Crabtree & Havey quarry** is in the town of Sullivan, three-fourths mile from Sullivan River. Operators, H. H. Havey & Co., North Sullivan.

The granite (specimen D, XXVI, 69, b) is a biotite granite of medium-gray shade and fine to medium even-grained texture. It consists, in descending order of abundance, of milk-white potash feldspar (microcline and orthoclase), smoky quartz, milk-white soda-lime feldspar (oligoclase), and black mica (biotite), together with accessory magnetite. The stone from the lower sheets is a trifle darker than that described above, which represents the stone of the upper sheets. The difference lies in the feldspar.

The quarry, opened in 1865, measured in 1905 300 feet from north to south, 200 feet from east to west, and 10 to 50 feet in depth.

Rock structure: The sheets, 3 to 8 feet thick, dip 10° W. and NW. In the center of the quarry they have a lenticular form (Pl. XIII, *A*, *B*). Vertical joints strike N. 80°–85° W., forming a heading on the north, also N. 10°–20° E., bounding the quarry on the east. A diabase dike, 3 feet wide, occurs on the west side, faulted in two places with a displacement showing a thrust from the east. The rock contains many knots, some of them 6 inches and a few 3 feet in diameter. Sap occurs along the sheets, but not invariably.

Transportation, by cart three-fourths mile to wharf.

The product is used mainly for curbing and crossings. The small beds go into paving blocks.

The **Stimson quarries** are in Sullivan. Operator, Ernest C. Gordon, Sullivan.

The granite (specimen D, XXVI, 67, (a) is a biotite granite of medium-gray shade and fine to medium even-grained texture, consisting, in descending order of abundance, of gray potash feldspar (orthoclase and microcline), smoky quartz, grayish soda-lime feldspar (oligoclase), and black mica (biotite), together with accessory magnetite. The biotite plates measure up to 0.15 inch across. Contrasts are slight, owing to similarity in color of quartz and feldspar.

The quarries consist of three openings, the main one of which is 200 feet square and from 15 to 30 feet deep.

Rock structure: The sheets, 1 to 5 feet thick, are horizontal, with slight undulations. Vertical joints strike N. 65° W., forming headings on the north and south sides, also north, and are coated in places with pyrite. The rift is horizontal. A vertical dike of aplite 1 foot 7 inches thick has a N. 10°–15° W. course. The amount of sap is small. Dark-gray knots up to 2 inches and exceptionally 7 inches in diameter occur.

The product is carted half a mile to a wharf.

The **Dunbar quarry** is 2½ miles northwest of Sullivan village, in the town of Sullivan. Operators, Dunbar Bros., Sullivan.

The granite is a biotite granite of medium-gray shade and coarse inclining to medium even-grained texture like that of the Robertson quarry, in Franklin, described on page 218.

The quarry, opened in 1901, measured in 1905 250 by 100 feet and 4 to 8 feet in depth.

Rock structure: Sheets, 2 to 12 feet thick, undulate with a general easterly dip of 10°. Vertical joints strike N. 80—85° E., forming a heading on south side of quarry, and N. 60° E. with a heading; also exceptionally N. 5°–10° E. The rift is horizontal. A diabase dike, 8 to 16 inches thick, has a course N. 20°–25° E. and rims of epidote, as described on page 52. There is little or no sap, and knots are few.

Transportation, by cart 1¼ miles to wharf.

The product is random stone, curbing, and paving.

Hooper, Havey & Co.'s quarry is in North Sullivan. Address, North Sullivan.

The granite is a biotite granite of medium-gray shade and fine to medium even-grained texture, like that of the Crabtree & Havey quarry (specimen D, XXVI, 69, a, described on page 230.

The quarry, opened about 1894, measured in 1905 300 by 150 feet by 15 to 20 feet in depth.

Rock structure: The sheets, 6 inches to 6 feet thick, are gently undulating and horizontal. Vertical joints strike N. 20–25° E., forming the west side of quarry, and also east, forming a heading on its north side. The rift is horizontal, and the grain vertical, east-west. The rock is evidently under a compressive east-west strain, as it tends to fracture in a north-south direction across the grain, without regard to knot holes. The knots are small.

Transportation, by cart half a mile to wharf.

The product is random stone and street material, and curbing (straight and circular), crossings, and paving blocks.

The **Pettee quarry** (black-granite) is three-fourths mile north of East Sullivan, on the road to Tunk Pond. Owner, J. A. Pettee, East Sullivan.

This rock (specimen D, XXVI, 80, b) is a mica-quartz diorite of very dark gray shade and fine to medium texture with occasional porphyritic whitish feldspar up to 0.25 and rarely 0.5 inch. It consists, in descending order of abundance, of white translucent soda-lime feldspar (oligoclase-andesine), black hornblende, opalescent quartz, black mica (biotite), and magnetite, together with accessory titanite, apatite, and pyrite. It takes a fine polish, and the contrast between polished and cut surfaces is marked. The diorite of East Sullivan is referred to by W. O. Crosby[87] in a paper on the geology of Frenchmans Bay.

The quarry, which is only 15 by 15 feet and 8 feet deep, is on the west side of a knoll 20 to 25 feet high.

Rock structure: Vertical joints, strike N. 25° W. and N. 85° W., recur at intervals of 1 to 5 feet. The rock splits in these directions, also horizontally.

[87] Boston Soc. Nat. Hist. Proc., vol. 21, p. 110, 1880.

There are whitish bands or veins 0.5 inch thick, consisting almost entirely of the feldspar and quartz.

This stone is quarried occasionally in small blocks for monuments.

The **Sinclair prospect** (black-granite) is 1½ miles north of East Sullivan, on Herbert and Thaddeus Sinclair's (formerly Smith Bean's) farm, near Charles Dowel's sawmill.

This rock (specimen D, XXVI, 82, a) is a mica-quartz diorite of almost black shade, with white blotches, of medium to coarse porphyritic texture. It consists, in descending order of abundance, of bluish opalescent quartz, whitish soda-lime feldspar (oligoclase-andesine), and potash feldspar (microcline and orthoclase), black hornblende, and black mica (biotite), together with accessory magnetite, pyrite, titanite, and apatite. Some of the feldspars measure nearly an inch in length.

The ledge is exposed for a length of 50 feet north-south and a height of 20 feet. A vertical joint strikes N. 20° W. An opening 10 by 5 feet and 5 feet deep was made here in 1902.

SWANS ISLAND.

The **Baird quarry** is on Swans Island, east side of old harbor, not quite 1 mile east of Swans Island village and three-fourths mile southeast of Minturn. Operator, Matthew Baird Contracting Co., 433 East Ninety-second Street, New York. Idle since 1917.

The granite (specimen D, XXVI, 34, a) is a biotite granite of medium pinkish-buff color and of medium inclining to coarse even-grained texture. It consists, in descending order of abundance, of a pinkish-buff potash feldspar (orthoclase and microcline), smoky quartz, a milk-white soda-lime feldspar (oligoclase), and black mica (biotite), together with accessory magnetite and, rarely, a little greenish hornblende. The potash feldspars are intergrown with plagioclase and measure up to 0.5 inch or more, but most of the biotite is considerably under 0.1 inch. The stone takes a good polish, but the contrast between the polished and rough surface is feeble, owing to the smallness of the biotite scales. The contrasts are mostly between the quartz and the feldspars. The company reports a test of crushing strength between 18,000 and 19,000 pounds to the square inch.

The quarry, opened in 1901, measured in 1905 500 by 250 feet, with an average depth of 15 to 18 feet.

Rock structure: The sheets, 1 to 7 feet thick, dip 15° S. Vertical joints, striking N. 45° E., recur at intervals of 50 feet; others, striking N. 80° W., recur but twice as continuous joints. The rift is vertical north-south. Sap is confined to the sheets of the upper 3 feet. No knots or veins.

Transportation, by gravity and cable on track 1,200 feet to wharf.

The product is random, dimension, and paving stone, which go to New York, where the firm has its cutting works.

The **Toothachers Cove quarry** is near the end of that cove, in the western part of Swans Island, 1½ miles north-northwest of Swans Island village. Quarry disused in 1905; also in 1917.

The granite (specimen D, XXVI, 33, a) is a biotite granite of medium pinkish-gray color and coarse, even-grained texture, with feldspars up to 0.75 inch and biotite fully 0.1 inch. It consists, in descending order of abundance, of light-pink potash feldspar (orthoclase), smoky quartz, cream-colored soda-lime feldspar (oligoclase), and black mica (biotite), together with accessory magnetite and titanite. The orthoclase is intergrown with plagioclase. The oligoclase is altered to a white mica. The contrasts between the four minerals are marked.

The quarry in 1905 was 50 by 25 feet, with a working face 20 feet high. There are two other small openings.

TREMONT.

The **Carroll quarry** is in the town of Tremont, on Mount Desert Island, at Southwest Harbor. Operator, John Carroll, Southwest Harbor.

The granite (specimen D, XXVI, 65, a) is a hornblende granite of pinkish-greenish medium-gray color and medium even-grained texture, consisting, in descending order of abundance, of pinkish-greenish potash feldspar (microcline), smoky quartz, very dark green hornblende, and very little black mica (biotite), together with accessory magnetite and zircon and secondary chlorite. The microcline is intergrown with quartz and soda-lime feldspar (oligoclase-andesine) and is largely altered to kaolin and a white mica. This granite is like that of the Graves quarry (specimen D, XXV, 64, a, p. 224) but is fresher.

The quarry is 100 feet from north to south by over 30 feet from east to west and in 1905 had a working face on the east 15 feet high. The sheets, 6 inches to 3 feet thick, are horizontal at the north end but dip 10° S. at the south end. Vertical joints strike N. 75° E. and N. 50°–55° W. Knots are abundant and are up to 2 feet in diameter.

The quarry is worked only occasionally, and the stone is used locally for foundations.

KENNEBEC COUNTY.

HALLOWELL.

The **Stinchfield quarry** is in the town of Hallowell, 2½ miles northwest of the city of Hallowell, on the southern part of Lithgow Hill. (See map, Pl. IX.) Operator, Hallowell Granite Works, C. B. Paine, receiver, Hallowell.

The granite (specimen D, XXVI, 111, a), "Hallowell," is a biotite-muscovite granite of light-gray shade and fine texture, with porphyritic feldspars usually about 0.25 inch in diameter. It consists, in descending order of abundance, of slightly bluish translucent potash feldspar (orthoclase and microcline), smoky (light) quartz, soda-lime feldspar (oligoclase) of the same color as the other, black mica (biotite), and white mica (muscovite), together with accessory garnet, zircon, and apatite. The oligoclase is usually undergoing alteration to kaolin and a white mica and contains intergrowths of quartz circular in cross section. Exclusive of the porphyritic feldspars, the general diameter of the particles ranges from 0.25 to 1.0 millimeter, averaging about 0.65. The micas are thickly disseminated. The stone takes a fine polish and the polished face has a slight bluish tinge. A microscopic description of "Hallowell granite" will be found in Merrill's "Stones for building and decoration," pages 63, 64.

E. C. Sullivan, of this Survey, found that this granite contains 0.060 per cent of CO_2 (carbon dioxide) and that warm dilute acetic acid dissolves 0.08 per cent of CaO (lime) and a trace of MgO (magnesia). If all of this CO_2 is assigned to the CaO, the rock contains 0.14 per cent of $CaCO_3$ (calcium carbonate). The lime extracted by this process is in addition to that combined with silica in the soda-lime feldspar. The thin sections from the Tayntor quarry stone, which is essentially the same, show a little carbonate (see p. 235), and the same mineral must occur also in this granite, but in very minute quantity.

A test of the crushing strength of this granite made by Ricketts & Banks yielded the following results:

	Pounds per square inch.
First cube	19,260
Second cube	15,730
Average	17,495

The difference in the two cubes is attributed to some imperfection in the second one.

The quarries were opened about 1826. The Stinchfield quarry measures 600 feet from northeast to southwest by 400 feet across and in 1905 was 30 to 60 feet deep. (See Pl. XII, *B*.) The Longfellow quarry (not in operation, but filled up to 20 feet with water), southwest of the Stinchfield and communicating with it, measures about 400 by 200 feet and from 50 to 70 feet in depth. The stripping comprises up to 20 feet (increasing northwestward) of yellowish sandy clay with small boulders near the top.

Rock structure: The most striking features in these quarries are the gradual increase in the thickness of the sheets downward (partly shown in Pl. XII, *B*), from 4 inches to 14 feet, and the evidence of strain afforded by the numerous headings and joint systems shown in figure 53, also the evidence of weathering afforded by the decomposition and discoloration along these headings. The sheets range from the horizontal to an inclination of 15° NE. Many of them stop at the joints, probably owing to faulting; some taper out and overlap. Plate XVII, *B*, a view of a part of the northwest wall of the Longfellow quarry,

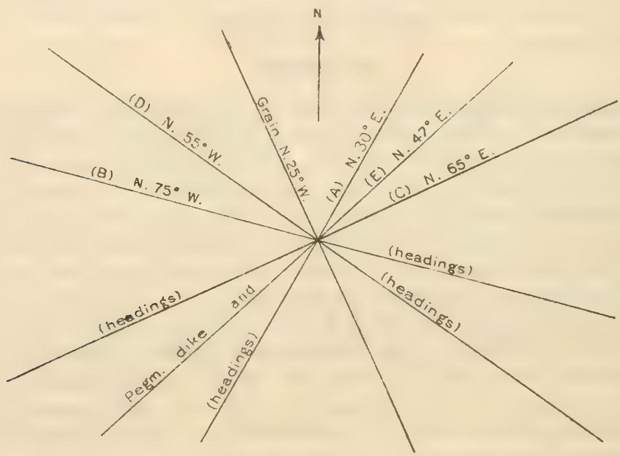

FIGURE 53.—Structure at Stinchfield and Longfellow quarries, near Hallowell, Maine.

shows the intersection of headings of joint systems (C) and (D). Joints (A) are spaced from 10 to 15 feet. (B) forms a heading 50 feet wide on the southeast wall, weathered yellow to a depth of 50 feet from the rock surface. Joints (C) are spaced from 5 to 70 feet. In a 2-foot heading of (C) on the southwest wall the joints recur at intervals of 2 inches to 0.5 inch and are coated with quartz crystals. Joints (D) form two headings, 10 feet wide, on the southeast wall, containing a bed of sand a foot thick and 30 feet deep or long. Joints (E) are discontinuous and grooved and polished from motion. Large areas of some of the joint planes in the Longfellow quarry are covered with frostlike crystallizations of oxides of iron and probably of manganese. The rift is horizontal; the grain is vertical, N. 25° W., but feeble. A 2-foot pegmatite dike contains milk-white oligoclase, smoky quartz, muscovite, biotite, and 1-inch garnets. Knots occur up to 0.75 inch across, exceptionally 1 by 3 inches. The sap is very marked along the joints and up to a foot thick. The concentric growth of ferruginous stain is shown in the heading photographed.

Transportation, by cart 2½ miles to railroad or to wharf on Kennebec River at Hallowell, accessible to schooners of 12-foot draft.

The product is used for buildings and sculpture. It lends itself remarkably well to delicate ornamental work and statuary, as is shown by Plate XX, a reproduction of a photograph of a panel at the entrance to the Bank of Commerce in New York, and by Plate XXI, representing a statue on the Hall of Records in the same city. In 1905 about seven-eighths of the product went into building and one-eighth into carved work. Speciment buildings: Capitol, Albany, N. Y.; Marine National Bank, Buffalo, N. Y.; Hall of Records (including its statuary), Brooklyn Savings Bank, New York; Masonic Temple, Boston; academic and library buildings, United States Naval Academy, Annapolis, Md.; vestibule of Terminal Station, Chicago; Northwestern Insurance Co.'s building, Milwaukee; Savings Bank, Bangor, Maine. Specimen monuments and statues: Statue on Pilgrim monument, Plymouth, Mass.; national monument, Yorktown, Va.; New York State monument, Gettysburg, Pa.; soldiers' monument,

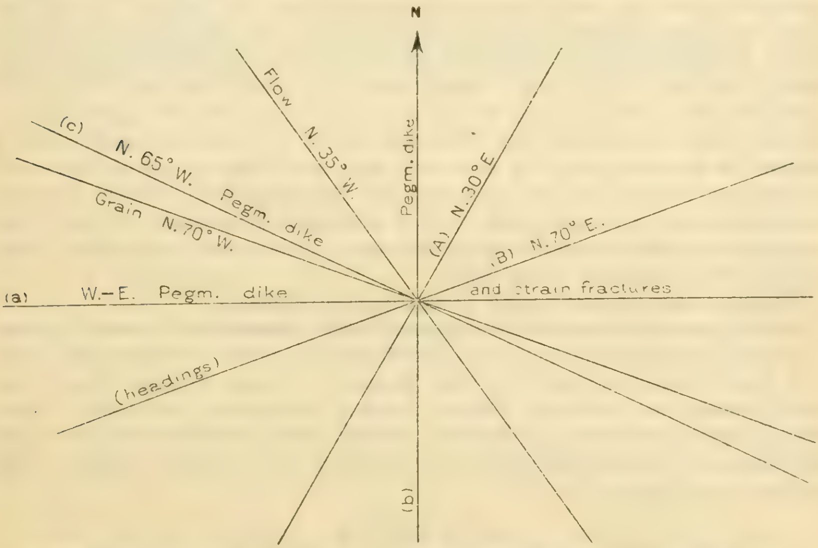

FIGURE 54.—Structure at Tayntor (Melvin) quarry, near Hallowell, Maine.

New Haven, Conn.; Richard M. Hunt monument, Central Park, New York; battlefield monument, Trenton, N. J. In 1922 the quarry was leased to Geo. A. Fuller Co. and was supplying part of the stone for the new courthouse in New York.

The **Tayntor quarry** (Melvin quarry) is in the town of Hallowell, 2 miles north-northwest of the city of Hallowell. It is now owned by the Hallowell Granite Works, but has not been operated for several years.

The granite, "Hallowell," is a biotite-muscovite granite of light-gray shade and fine (but porphyritic) texture, identical with that of the Longfellow and Stinchfield quarries (specimen D, XXVI, 111, a), described on page 233. The general diameter of particles, exclusive of the porphyritic crystals, ranges from 0.25 to 1.25 millimeters. One of the small porphyritic oligoclase crystals measuring 2.25 millimeters in diameter shows calcite between its cleavage planes. Calcite appears also independently in plates up to 0.5 millimeter across. E. C. Sullivan, of this Survey, found that it contained 0.146 per cent of CO_2 (carbon dioxide) and that warm dilute acetic acid extracted 0.24 per cent of CaO (lime) and no magnesia. The CO_2 found corresponds to 0.33 per cent of $CaCO_3$

(calcium carbonate). The difference in the result of the test of this and the test of the Stinchfield quarry stone may not hold good of the stones in general. The average of both tests, or 0.235 per cent for the lime carbonate of both stones, may be nearer the truth.

The quarry, opened before 1840, measured in 1905 520 feet N. 30° W. to S. 20° E. by 275 feet across and from 10 to 40 feet in depth. The deeper part of it is 275 by 150 feet and 40 feet deep.

Rock structure: In places there is a vertical flow structure with course N. 35° W., and where it occurs it is the direction of easiest fracture. The sheets measure 1 foot to 6 feet 6 inches (the thicker being the lower ones), and are horizontal. The joint and dike courses are shown in figure 54. (A) recurs at intervals of 20 to 200 feet, and forms one heading, which does not extend beyond a depth of 15 feet from the rock surface. (B) in places dips steep north, recurs at intervals of 10 to 40 feet, and forms headings in the northern half of quarry. The rift is horizontal, and the grain vertical, N. 70° W., but feeble. Figure 54 shows the courses of the pegmatite dikes; (a) dips 45° N. and is 4 inches thick, (b) dips 65° E. and is 3 inches thick, (c) dips N. and is 3 inches thick. Pegmatite lenses 2 feet thick also occur. In the northern part of the quarry there is a band of dark knots, from 5 to 25 feet wide, with a N. 10° E. course, but the rest of the quarry is free from knots. The glaciated surfaces and the sheet surfaces are free from sap except near the headings, where it extends for 6 inches from each sheet and joint face. The granite is here under compressive strain, for the cores between the contiguous borings made in channeling become crushed, and on two occasions spontaneous vertical east-west fractures 40 feet long occurred through a sheet 4 feet inches thick, diagonal to two rectangular "channels."

Transportation, by rail 2 miles to cutting shed at dock.

The product was used for monumental work. Specimens: General Slocum monument, Gettysburg, Pa.; State of Maine monument, Andersonville, Ga.; New York State monument, Lookout Mountain (Craven House), Tenn.; soldiers' monument, Pittsfield, Maine; Dunlap mausoleum (Corinthian style, 16 by 28 feet) and Ziegler mausoleum (Grecian Doric style, 25 by 34 feet, after the temple at Paestum), Woodlawn Cemetery, New York; General Miles mausoleum, Arlington, Va.

KNOX COUNTY.

MUSCLE RIDGE PLANTATION.

The **High Isle quarry** is in Muscle Ridge Plantation, 9½ miles south-southeast of Rockland. Operators in 1905, William Gray & Son, Philadelphia, Pa. Quarry now idle.

The granite (specimen D, XXVI, 18, a) is a biotite granite of slightly pinkish medium-gray color, with conspicuous black mica and of medium to coarse, even-grained texture, the feldspars measuring up to 0.5 inch and most of the biotite scales up to 0.1 inch, but some 0.2 inch. It consists, in descending order of abundance, of a delicate pink potash feldspar (orthoclase and microcline), smoky quartz, milk-white, very slightly bluish soda-lime feldspar (oligoclase), and black mica (biotite), together with accessory magnetite, apatite, and secondary chlorite. The oligoclase is in some places partly altered to a white mica. The contrasts between the minerals are rather marked, but the polish is not very satisfactory, owing to the large size of the biotite scales.

The following chemical analysis and determination of specific gravity were made for the firm by Prof. James F. Kemp, of Columbia University:

Analysis of granite from High Isle quarry.

	Per cent.
Silica (SiO_2)	74.54
Alumina (Al_2O_3)	13.30
Ferrous oxide (FeO)	.79
Ferric oxide (Fe_2O_3)	.92
Lime (CaO)	1.26
Magnesia (MgO)	.009
Manganese (Mn)	.51
Sulphur (S)	.038
Soda (Na_2O)	3.69
Potash (K_2O)	5.01
	100.067

Loss on ignition, 0.55.

Specific gravity, 2.641, equal to 165.06 pounds per cubic foot.

The results of three crushing tests (laboratory Nos. 1759 to 1761) on 2-inch cubes bedded with plaster of Paris, made at the engineering laboratory of

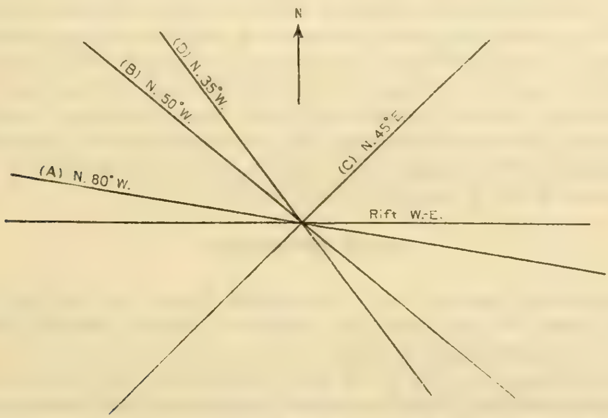

FIGURE 55.—Structure at High Isle quarry, Knox County, Maine.

Columbia University for the firm, are as follows: First crack at 100,000 to 126,300 pounds. Ultimate strength in pounds per square inch, 25,880, 32,360, 32,495, 33,085.

The quarry, opened about 1894, consists of five openings, each about 100 feet square, with a maximum depth of 50 feet and an average depth of about 17 feet.

Rock structure: The sheets, 2 to 14 feet thick, are lenticular, tapering, and curve over to the northwest and southeast at low angles. (See Pl. XVI, *A*.) Joint courses are shown in figure 55. (A) is prominent and forms a heading on the south side of the island, shown in Plate XVI, *A*. (B) dips 40° SE., occurs but occasionally, and is discontinuous. (C) also forms a heading. (D) dips 65° SW. and is also prominent. The rift is vertical, with east-west course. Irregular horizontal dikes of pegmatite, up to 2 inches thick, consist of the same minerals as the granite—a pink orthoclase and microcline, smoky quartz, cream-colored oligoclase, and biotite. Sap occurs along the sheets and joints (A) and (C), and markedly at the surface, in places up to a foot in thickness. (For details see p. 66 and fig. 5.) Along some of the headings of (A) the granite is weathered to a sand at a depth of 20 feet.

Transportation, by gravity and track 650 feet to wharf.

The product was used for buildings. Sundry small buildings and bridge seats for the Pennsylvania Railroad have been made of this stone; also the new Wanamaker store in Philadelphia.

The **Dix Island quarries** are in Muscle Ridge Plantation, half a mile southwest of High Isle. Owner, Thomas Dwyer, Two hundred and sixteenth Street and Broadway, New York. Quarries abandoned.

Six openings were operated extensively in 1880 by the Dix Island Granite Co., which employed 1,400 men when filling large contracts. These quarries furnished material for the United States Treasury Department extension at Washington, the basement of the Charleston customhouse, the New York and Philadelphia post offices, and the trimmings for the New York Metropolitan Museum of Art. Only an occasional block is now quarried. There is a wharf with 12 feet of water at low tide.[88]

The granite (specimen, D, XXVI, 19, a) is a biotite granite of somewhat dark-gray shade and of medium to coarse, even-grained texture, with feldspars up to 0.5 inch and many fine biotite scales rarely over 0.1 inch. It consists, in descending order of abundance, of delicate pink potash feldspar (orthoclase and microcline), smoky quartz, a very slightly bluish-white soda-lime feldspar (oligoclase), and black mica (biotite), together with accessory magnetite and apatite. The oligoclase is partly altered to a white mica and rarely contains a little calcite. The biotite is here and there interleaved with muscovite. The chief difference between this and the "High Isle granite" is that in this the biotite scales are generally smaller and much more abundant, which darkens the shade of the rock and diminishes the contrast between the minerals.

Rock structure: The sheets, 2 to 10 feet thick, dip 20°–40° S. in places. Headings strike N. 80° E. and N. 35° W.

SOUTH THOMASTON.

The **Sprucehead quarry** is on Sprucehead Island, in the town of South Thomaston, about 10 miles south of Rockland. Owner, Bodwell Granite Co., Rockland. Quarry disused since 1910

The rock (specimen D, XXVI, 10, a), "Sprucehead," is a quartz monzonite, with conspicuous black, white, and gray particles and of medium to coarse, even-grained texture. It consists, in descending order of abundance, of translucent white soda-lime feldspar (oligoclase), milk-white potash feldspar (microcline), smoky quartz, black mica (biotite), and black hornblende, together with accesory titanite, magnetite, pyrite, zircon, apatite, and secondary epidote. Zonal structure is common in the oligoclase. The contrasts between the black minerals, the smoky quartz, and the feldspars are very marked.

The quarry in 1905 was about 275 feet by 250 feet and had a maximum depth of 55 feet and an average depth of about 27 feet.

Rock structure: The sheets, from less than a foot to 13 feet thick, lie horizontal or dip 10°–15° NW. and SW., intersecting the surface, which dips gently southeast. The sheets are irregular in thickness, owing to the tapering out of the lenses, but, in general, increase in thickness downward. Joints and dike courses are shown in figure 56. (A) recurs frequently on the north side of the quarry, but two joints are 50 feet apart and have greatly facilitated the opening of the quarry. (B) dips 70° N. and traverses the entire quarry. The rift is vertical with a N. 60° E. course. Knots and dikes occur. Sap is 3 inches thick on the sheet surfaces.

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[88] These quarries are referred to by J. E. Wolff in Tenth Census, vol. 10, pp. 119, 120, 1888, and by G. P. Merrill in Smithsonian Inst. Ann. Rept., 1889, pt. 2, p. 416.

Transportation, by cart 300 feet to wharf.

Specimen buildings, etc.: Carnegie Library, Allegheny, Pa.; post office and customhouse, Atlanta, Ga.; columns of Auditorium Building, Chicago; Mutual Life Insurance Co.'s building and National City Bank, New York; post office (exterior), Bar Harbor, Maine.

The **Weskeag quarry** is in the town of South Thomaston, 1 mile west of Pleasant Beach and 7 miles south of Rockland. Quarry disused since 1914.

The granite (specimen D, XXVII, 142, a) is a biotite-muscovite granite of slightly bluish medium-gray color and of medium to coarse, even-grained texture, with feldspars up to 0.5 inch and mica to 0.15 inch. It consists, in descending order of abundance, of light-bluish potash feldspar (orthoclase and microcline), smoky quartz, bluish or white soda-lime feldspar (oligoclase), black mica (biotite), and white mica (muscovite), together with accessory garnet, magnetite, and apatite. The oligoclase is partly altered to kaolin and a white mica. Thin sections show a marked rift.[89] The stone takes a fine polish, but

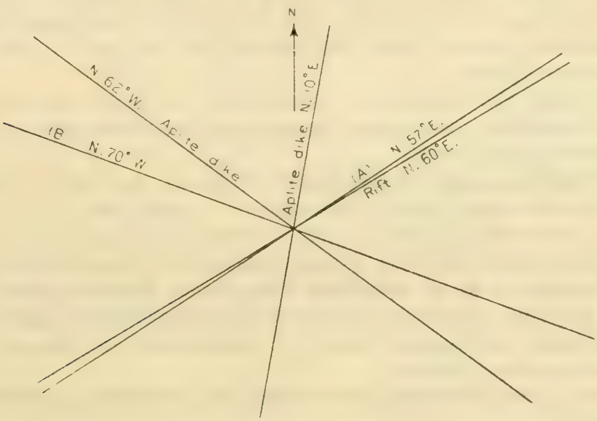

FIGURE 56.—Structure at Sprucehead quarry, South Thomaston, Maine.

the abundance and size of the mica plates are not favorable to the durability of the polish under outdoor exposure.

The quarry, reopened in 1905, covered then about an acre of ground with an average depth of 20 feet. The sheets are horizontal and tapering, lenticular. Joints strike N. 80° E. and dip 80° S. Rift is vertical and strikes N. 80° E. Grain is horizontal.

Transportation, by cars and horsepower on track half a mile to wharf near Birch Point.

ST. GEORGE.

The **Clark Island quarry** is on Clark Island, in the town of St. George, about 12 miles south-southwest of Rockland. Owner, Rodgers Granite Corporation, 271 West One hundred and twenty-fifth Street, New York.

The granite (specimen D, XXVI, 12, a) is a biotite-muscovite granite of bluish, medium-gray color and of fine to medium even-grained texture, with feldspar up to 0.25 inch and mica under 0.1 inch. It consists, in descending order of abundance, of light-bluish potash feldspar (microcline and orthoclase), clear or very slightly smoky quartz, light-bluish soda-lime feldspar (oligoclase), black mica (biotite), and white mica (muscovite), together with

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[89] See U. S. Geol. Survey Bull. 313, fig. 1, 1907.

accessory garnet, zircon, apatite, and secondary chlorite. The oligoclase is partly altered to a white mica and includes a little carbonate. The quartz contains hairlike crystals of rutile. In general, as the quartz is so nearly clear, the bluish tint of the feldspar dominates and the contrast is mostly between it and the thickly disseminated black mica. It takes a very fine polish.

E. C. Sullivan, of this Survey, finds that it contains 0.218 per cent of CO_2 (carbon dioxide), and that warm dilute acetic acid extracts 0.24 per cent of CaO (lime), and much MgO (magnesia). Figuring the CO_2 to both CaO and MgO, this would give 0.43 per cent of $CaCO_3$ (calcium carbonate) and 0.06 per cent of $MgCO_3$ (magnesium carbonate). The thin section also shows carbonate.

The quarry, opened about 1870, measured in 1905 500 by 300 feet, with a maximum depth of 50 feet and an average of 25 feet.

Rock structure: The sheets, 2 to 10 feet thick, strike N. 30° W. and dip 20° E. and on the east side of the quarry 20°–30° W. Vertical joints strike N. 65°–70° W. and recur at intervals of 10 to 20 feet. The rift is vertical, with a N. 85° W. course. There are two dikes of coarse pegmatite, up to 6 inches thick, one striking N. 15° W., the other N. 40° E. They consist of feldspar, quartz, muscovite, biotite, black tourmaline, and red garnet. The usual sap occurs along the sheets.

Transportation, by horse power on track 900 to 1,200 feet to wharf.

Specimen buildings: Post offices, Hartford, Conn., and Buffalo, N. Y.; Standard Oil Building, New York.

The **McConchie quarry** (black-granite) is in the town of St. George, about three-fourths mile north of Long Cove quarry. Quarry idle.

The rock (specimen D, XXVI, 16, a), "Crown black granite," is a norite of very dark gray shade and fine to medium texture, consisting, in descending order of abundance, of an unaltered colorless to smoky feldspar containing both soda and lime (andesine to labradorite), hypersthene partly altered to brown hornblende, black mica (biotite) in scales up to 0.2 inch, and magnetite, together with accessory pyrite.

The quarry, opened in 1888, was in 1905 about 50 feet square and from 10 to 15 feet deep.

The stone has to be carried 10 miles to the cutting works at South Thomaston, although the quarry itself is within one-fourth mile of seaboard.

Specimen structures: Soldiers' monuments at Warren and Union, Maine.

The **Long Cove quarry** is near both Tenants Harbor and Long Cove, in the township of St. George, about 13 miles southwest of Rockland. (See Rockland topographic map, U. S. Geol. Survey.) Operator, Booth Bros. & Hurricane Isle Granite Co., 208 Broadway, New York.

The granite is a biotite-muscovite granite of bluish medium-gray color and of fine to medium even-grained texture like that of the Clark Island quarry, described on page 239. Tests of its compressive strength made by the Columbia School of Mines are reported by the firm to have shown an ultimate crushing strength of 22,000 pounds to the square inch, but the original report of these tests has been misplaced.

The quarry, opened about 1873, measured in 1905 about 1,000 feet from north to south by 500 feet from east to west and from 20 to 75 feet in depth, averaging about 40 feet. This is the only quarry in New England in which tunneling is resorted to in the use of explosives.

Rock structure: The sheets, 6 inches to 13 feet thick, are horizontal or dip 10°. Joints and dike courses are shown in figure 57. (A) recurs at intervals of 2 to 30 feet, (B) dips 25°, (C) dips 65° NE. The east end of the quarry is

much broken up by the closeness of joints (A) and the thinness of the sheets for a considerable distance below the surface. The rift is vertical, with N. 80°–90° W. course. There is a horizontal dike of pegmatite up to 9 inches thick at the north end of the quarry; another, divided into many parallel ones, strikes N. 70° W. and dips 70° N. These dikes all consist of white feldspar, quartz, muscovite, black tourmaline, and garnet. Sap is up to 18 inches thick along sheets and joints.

Transportation, by inclined track 900 feet to wharf.

The product is used chiefly for monuments and goes chiefly to Greenwood and other cemeteries near Brooklyn, N. Y. The small beds and waste are worked into paving blocks. Specimen buildings, etc.: Post office, Albany, N. Y.; Bates Building, Philadelphia; and part of Saratoga monument.

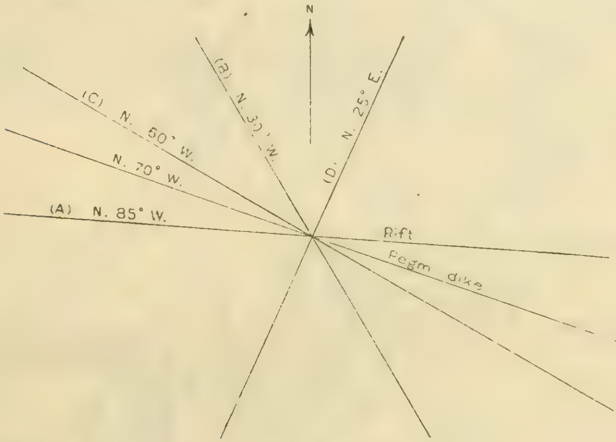

Figure 57.—Structure at Long Cove quarry, St. George, Maine.

The **Willards Point or Wildcat quarry** is on Tenants Harbor, in the township of St. George, about a mile south of the Long Cove quarry. Operator, St. George Granite Co., 90 West Street, New York.

The granite is a biotite-muscovite granite like that of the Long Cove and Clark Island quarries (p. 239).

The quarry, opened before 1873, measured in 1905 about 200 by 100 feet, with an average depth of 20 feet.

Rock structure: The sheets, 1 to 3 feet thick, are nearly horizontal. There are four sets of joints—(a), strike nearly due east; (b), strike N. 55° W.; (c), strike N. 70° E.; (d), strike N. 70° W. The rift is east-west. Pegmatite dikes, 6 to 12 inches thick, strike N. 30° W. and N. 50° W.

The quarry is only 300 feet from the dock.

Although the Rockland post office was made of this granite it is now used entirely for paving.

VINALHAVEN AND HURRICANE ISLANDS.

Vinalhaven and the adjacent islands have been known collectively as the Fox Islands, and their granite as "Fox Island granite." The granite industry of these islands is distributed over an area about 5 miles from east to west by 4 miles from north to south. The locations of the quarries are shown on the

map (fig. 58). Some of them are near the center of Vinalhaven Island. The Palmer quarry is on the west shore; the Black and Webster quarries are on the east shore; the Sands, Harbor, and Armbrust quarries are on the south shore, near Vinalhaven village; and the Pequoit and Duschane Hill quarries lie east of the village near the east shore. There are some minor

FIGURE 58.—Map showing location of quarries on Vinalhaven and adjacent islands, known collectively as "Fox Islands," Maine. (From Vinalhaven topographic map, U. S. Geol. Survey.)

quarries ("motions") on Barton, Cundell, and Green Islands, and a large quarry on Hurricane Island. As will be seen from the descriptions, there is little difference between the coarse granites of the Hurricane Island, Sands, Harbor, Armbrust, Black, Webster, and Palmer quarries, but the granites of the Duschane Hill and Pequoit quarries are fine textured, as is also that from an abandoned opening in Vinalhaven village.

Plate X, *A*, shows the conspicuous east-west jointing in the granite on Heron Neck, at the south end of Green Island. The same system of joints recurs on Hurricane Island and at the Sands and Armbrust quarries.

The **Sands quarry** is in the town of Vinalhaven, at the northeast side of the head of Sand Cove. (See maps, Pl. IX and fig. 58). Operator, Bodwell Granite Co., Rockland. Idle in 1922.

The granite (specimen D, XXVI, 1, b) is a biotite granite of general pinkish-buff color and of coarse, even-grained texture, the feldspars measuring up to 0.75 inch (rarely 1 inch) and the biotite scales up to 0.2 inch. It consists, in descending order of abundance, of a pinkish-buff potash feldspar (chiefly orthoclase with some microcline), smoky quartz, milk-white soda-lime feldspar (oligoclase), and black mica (biotite), together with accessory magnetite, zircon, and apatite. The orthoclase here and there contains irregular areas of carbonate and is intergrown with a plagioclase or rimmed with oligoclase. The oligoclase is partly altered to kaolin and a white mica. Pyrite is found by the quarrymen in rare and minute particles, and molybdenite occurs occasionally in half-inch scales. E. C. Sullivan, of this Survey, finds that this granite con-

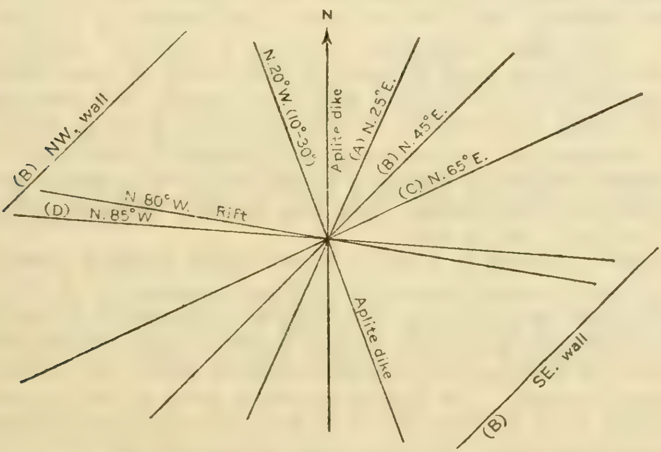

FIGURE 59.—Structure at Sands quarry, Vinalhaven, Maine.

tains 0.034 per cent of CO_2 (carbon dioxide) and that warm dilute acetic acid extracts 0.07 per cent of CaO (lime) and a trace of MgO (magnesia). This, if the CO_2 is allotted to the CaO, shows a percentage of 0.08 of $CaCO_3$ (calcium carbonate), the presence of which is also indicated by the microscope. The stone takes a fine polish, but the size of the mica plates does not favor the durability of the polished face under continued exposure. The contrasts of color and shade are chiefly between the two feldspars and the black mica.

The quarry, opened before 1860, measured in 1905 about 500 feet from northeast to southwest and about the same distance from northwest to southeast, and was 20 to 75 feet deep, averaging about 40 feet. The exacavation has not only cut down a granite hillock but has extended below the general land level. Plate XIV, *A*, shows the south-southeast end of the quarry.

Rock structure: The sheets, 1 to 20 feet thick—generally, however, from 2 to 10 feet—lie flat along an east-west axis for a width of about 200 feet but on either side curve over gently to the north and south, with dips of 5°, 10°, and 20°. The joint and vein courses are shown in figure 59. Joints (B) form the northwest and southeast walls of the quarry. Joints (C) are coated in places

with crystalline calcite to the thickness of 0.25 inch, or with hematite, chlorite, and stilbite in microscopic films. (Determination of stilbite by W. T. Schaller, of this Survey.) The rift is vertical, with a N. 80° W. course. The "hard way" or "cut off" is N. 10° E. Blocks 65 and 120 feet long have been obtained by splitting along the rift. The thickness and curvature of the sheets, the intersecting joint face, and the channeling along the "cut off" are shown in Plate XIV, *A*. Dikes of grayish aplite, described on page 43, are 1 to 7 inches thick. There are some dark-gray knots (see p. 59) of more biotitic granite, up to 2 feet in length and 4 inches in width, and some of spheroidal form, with a diameter of 2½ feet. Sap is 4 inches thick on either side of joints (A), (B), (D), and also along the sheet surfaces. The unhewn weathered surface about the quarry passes into a granite sand, with little or no staining by limonite.

Transportation, by railroad 500 feet to wharf, which admits schooners and barges of 1,500 gross tons capacity.

The product is used for docks, bridges, piers, buildings, and monuments. The thin sheets and much of the waste are made into paving blocks 12 by 4 by 7 to 8 inches. Plate XIX, *A*, shows how the granite of this quarry lends itself to coarse sculpture. Specimen structures made exclusively of Sands quarry granite: Post Office Department building, Washington; Masonic Temple, Philadelphia; savings bank, Wilmington, Del.; board of trade building, Chicago; post office and customhouse, Brooklyn; General Wool monument, Troy, N. Y.; Manhattan Bank, New York. The Sands quarry and the Palmer quarry together furnished all the stone for the customhouse in New York.

The **Palmer or Wharff quarry** is in the town of Vinalhaven, on the west side, opposite Leadbetter Island. (See map, fig. 58.) Operator, Bodwell Granite Co., Rockland. Idle in 1922.

The granite (specimen D, XXVI, 2, b) is a biotite granite of general pinkish-buff color and of coarse texture, the feldspar measuring up to 0.75 inch and the biotite scales up to 0.2 inch. It is identical with that of the Sands quarry (p. 243), except that the potash feldspar is a little more pinkish buff and the white soda-lime feldspar is of a slightly greenish tinge. The general tone of the color is "warmer." The thin section shows rarely a little hornblende.

The quarry is on the west side of a ridge 100 feet high. It measured in 1905 about 500 feet square, with an average depth of 25 feet.

Rock structure: The sheets dip 10° W. in the front (western) part of the quarry, but gradually turn at the back or working face to 10° E. They are 4 to 15 feet thick. About 20 feet below the top of the quarry face is a bed of granite sand, 18 inches thick, parallel to the sheets, already referred to on page 70. The principal joints, which strike N. 80° W. and dip 80° S., form a 5-foot heading at the south end of the quarry and recur but once or twice. The rift is vertical, striking N. 10° E. Owing to the structure here, it is usual to blast by lewis holes along the grain (east-west) and then to split by plug drilling along the rift; in this way thick sheets can be split along the grain a distance of 200 feet. One block loosened measured 300 feet along the grain by 120 feet along the rift and was 15 feet thick. Dikes of aplite are rare. A knot from this quarry is described in detail on page 59. Sap is up to 6 inches thick along sheet and joint surfaces. It is intense in color at the surfaces.

Transportation, by rail 700 feet to wharf, where the blocks are taken on schooners either to the cutting sheds at the Sands quarry or directly to market.

The product is used chiefly for bridges and buildings, and the waste is made into paving blocks. This quarry, in common with the Sands quarry, furnished the material for the New York customhouse. It supplied also eight columns, 51½ to 54 feet long by 6 feet in diameter, for the Cathedral of St. John the

Divine in New York. It was intended that they should each be of one piece, but as both the direction of the rift at the quarry and architectural principles required that they be cut with their long axes at right angles to the rift, the strain in the great lathe came upon the weakest part of the stone. However, as the first stone put into the lathe broke with a long diagonal fracture, it became evident that the chief difficulty was that the stone had been subjected to too great a torsional strain by the application of rotary power from one end only. It therefore became necessary to make each column of two sections, each about 26 feet long. Plate XIX, *B*, shows the lathe with the first full-length column in it and three others as originally prepared for it.

Among the structures made of this granite since 1905 are the Chicago & Northwestern Railroad station, Chicago; State Savings Bank, Lansing, Mich.; West Street Building (two stories polished), United States Realty Building, 115 Broadway, and 97 per cent of the main piers (above foundation) of Hell Gate Bridge, New York.

The **Webster quarry** is in the town of Vinalhaven, on the north shore of "Pleasant River," at the end of Winter Harbor, in the northern part of Vinalhaven Island. (See fig. 58.) Operators in 1905, A. M. Webster & Co., Vinalhaven. Quarry now abandoned.

The granite is a biotite granite identical with that of the Palmer quarry, described above.

Rock structure: The sheets, 5 to 10 feet thick, dip 10°–15° N. 30° E. Vertical joints strike N. 30° W. and N. 60° E. The rift is vertical, with N. 30° W. course. There are some knots. A spherical one is 5 feet in diameter. Sap is 3-inches thick along sheets and joints.

Transportation, by a graded track 200 feet to wharf admitting schooners of 300 to 350 long tons. Plate XVIII, *A*, shows the quarry and a schooner laden with granite.[90]

The product, shipped in the rough, was used for buildings in New York and Boston.

The **Black (Pleasant River) quarry** is in the town of Vinalhaven, on the south shore of Pleasant River, at the end of Winter Harbor, in the northern part of Vinalhaven Island. Operator, Joseph S. Black, Vinalhaven. Idle since 1912.

The granite is a biotite granite, identical with that of the Palmer quarry, described on page 244.

The quarry, opened in 1896, measured in 1905 300 feet in a N. 40° W. direction by 200 across with a working face 45 feet high.

Rock structure: The unworked surface above the quarry is very free from joints, knots, and veins. The sheets, 10 to 12 feet thick, are horizontal at the working face or back of the quarry but at the front dip 10°–15° W. Vertical joints strike N. 20° E. The rift is vertical, with course N. 40° W. Knots are from 6 inches to 2 feet 6 inches in diameter.

Transportation, by a 350-foot track, with a grade of 10 feet, to wharf.

The product is used for building, the waste for riprap. The quarry has furnished material for the dry dock at Portsmouth, N. H., and the Rain Island Lighthouse.

The **Pequoit quarry** is in the town of Vinalhaven, 1¼ miles east-northeast of Vinalhaven village, on Vinalhaven Island. (See fig. 58.) Owner, Booth Bros. & Hurricane Isle Granite Co., 208 Broadway, New York.

The granite (specimen D, XXVI, 7, a) is a biotite-hornblende granite of medium-gray shade and fine, even-grained texture, with porphyritic feldspar

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[90] Mr. Webster built his own schooners and sailed them himself, laden with his own granite, quarried by a partner.

up to 0.25 inch in length. It consists, in descending order of abundance, of a translucent whitish potash feldspar (orthoclase, with a very little microcline), smoky quartz, a whitish soda-lime feldspar (oligoclase), black mica (biotite), and dark hornblende, together with accessory magnetite, titanite, and apatite. The orthoclase is here and there intergrown with a plagioclase. The orthoclase is in places altered to kaolin and a white mica and includes occasionally some carbonate. The porphyritic crystals are orthoclase.

The quarry, opened in 1887, consisted in 1905 of two openings, each about 250 feet square and about 10 feet deep.

Rock structure: The sheets, 1 to 6 feet thick, dip 10°–15° N. 80° W. Vertical joints strike N. 80° W. and N. 5°–10° E. The rift is vertical, striking N. 5°–10° E.

The product is carted one-third mile to the narrows and there shipped.

The product consists entirely of paving blocks (10 to 14 by 4 to 5 by 6 to 7 inches).

The **Duschane Hill quarry** is in the town of Vinalhaven, 1¼ miles east of Vinalhaven village, on Roberts Harbor. (See fig. 58.) Operator, Roberts Harbor Granite Co., Vinalhaven.

The granite (specimen D, XXVI, S, a) is a biotite granite of medium buff-gray color and of fine to medium porphyritic texture, with most of the feldspar about 0.2 inch long, but some 0.33 or 0.5 inch long. The rock consists, in descending order of abundance, of a buff-gray potash feldspar (orthoclase), smoky quartz, a buff-gray soda-lime feldspar (oligoclase), and black mica (biotite), together with secondary chlorite. The orthoclase is intergrown with plagioclase, and the oligoclase is partly altered to kaolin and a white mica.

This stone is used entirely for paving blocks.

The **Bodwell openings** (black-granite) are in the town of Vinalhaven, in the diabase area west of Sand Cove. Operator, Bodwell Granite Co., Rockland. Idle in 1922.

This rock (specimen D, XXVI, 1½, a) is an olivine norite of almost black shade and of fine texture, consisting, in descending order of abundance, of a network of usually slender crystals (from 0.37 to 1.66 millimeters in length) of grayish unaltered lime-soda feldspar (labradorite to bytownite), filled with hypersthene, greenish olivine, black mica (biotite), and magnetite. It takes a very fine polish and cuts white. It is not obtainable in very large blocks. This stone is referred to by George P. Merrill.[91]

The **Indian Creek quarry** is on Indian Creek in the township of Vinalhaven, about half a mile from Vinalhaven village. (See fig. 58.) Operators, J. Leopold & Co., 233 Broadway, New York.

The granite is reported by the Office of Public Roads, Department of Agriculture, as a light-gray biotite granite of medium grain, with a compressive strength of 21,220 pounds to the square inch.

The quarry was opened in 1909.

The product is used entirely for curbing and paving.

The **Armbrust quarry** is in the town of Vinalhaven, between Carvers Harbor and Indian Creek, south of Vinalhaven village. Operator, Crown Hill Granite Works, Vinalhaven.

The granite is a biotite granite similar to that of the Sands quarry described on page 243.

The quarry consists of numerous openings on several sides of a hillock 100 feet high. It has not been operated since 1907.

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[91] Tenth Census, vol. 10, p. 24.

Rock structure: The sheets, 3 to 15 feet thick, are mainly horizontal but on the east side of the hill dip 10° S. Vertical joints strike N. 75°–80° W. and N. 30°–35° E. There is no marked rift, but a vertical mass 4 feet thick, striking N. 65° W. across the hill, has a horizontal rift and greatly facilitates quarrying, as it serves the purpose of a channel.

Transportation: The product was carted in 7 to 10 ton loads one-fourth to one-half mile to a wharf on Carvers Harbor.

The product consisted entirely of paving blocks.

The **Hurricane Island quarry** is in the town of Vinalhaven, in the southeastern part of Hurricane Island. (See map, fig. 58.) Operator, Hurricane Isle Quarries Co., Rockland. Quarry abandoned.

The granite (specimen D, XXVI, 4, a) is a biotite granite of general pinkish-buff medium-gray color and of coarse, even-grained texture, the feldspars measuring up to 0.75 inch and the biotite scales up to 0.2 inch. It is identical with that of the Sands quarry, described on page 243. The potash feldspar is perhaps a trifle more pinkish buff than that of the Sands quarry but not quite so much so as that of the Palmer quarry. These distinctions, however, are small and may not hold throughout the quarries, although they characterize the typical specimens selected for the writer by the superintendents of the respective quarries.

The following chemical analysis of granite from Hurricane Island was made by Ricketts & Banks, of New York, for the firm (No. 16073), and is inserted here for reference merely.

Analysis of granite from Hurricane Island.

Silica (SiO_2)	70.94
Alumina (Al_2O_3)	15.68
Ferrous oxide (FeO)	2.29
Lime (CaO)	1.23
Magnesia (MgO)	.19
Manganese oxide (MnO)	.13
Soda (Na_2O)	3.58
Potash (K_2O)	5.54
Sulphur (S) total	.05
Carbon dioxide (CO_2)	None.
Loss and undetermined	.37
	100.00

A compression test made by Prof. Ira H. Woolson, of the Columbia School of Mines,[92] showed an ultimate crushing strength of 19,583 pounds to the square inch.

The quarry, opened about 1876, measured in 1905 500 feet along the rift (N. 85° W.) and had an average width of 150 feet. It lies on the south side of a ridge 100 feet high with a west-northwest axis. The greatest depth of working face was 105 feet and its average about 50 feet.

Rock structure: The sheets, 3 to 20 feet thick, curve over on both the north and the south side of the ridge, with a dip of not less than 10°. Seen from the western spur of the island, two 20-foot sheets form the upper part of the hill; beneath these, however, is a much thicker sheet, which at the east-southeast end of the hill and quarry measures fully 60 feet—too thick for economic work-

[92] Day, W. C., U. S. Geol. Survey Twentieth Ann. Rept., pt. 6, continued, p. 391, 1899 (test No. 1709).

ing. These sheets are shown in Plate XII, *A*, as seen looking northwest. This abnormally thick sheet is referred to by Merrill.[93] The sheets are traversed by three sets of joints, as shown in figure 60. (A) dips 50°–55° W.; (B) is vertical; and (C), which is diagonal to (A) and (B), dips 40° NE. The rift is vertical, with N. 85° E. course. The east-west system (B), which is parallel to the rift, reappears on Heron Neck. as shown in Plate X, *A*. (B) and (C) are both shown on Plate XII, *A*. The (B) surfaces are, in places, coated with epidote. Occasional knots occur.

Transportation, by track 400 feet to dock.

The product is used for buildings and monuments. The waste goes into paving blocks. Specimen buildings: Suffolk County courthouse, Boston; St. Louis post office and customhouse; two buildings for the Naval Academy at Annapolis, Md.

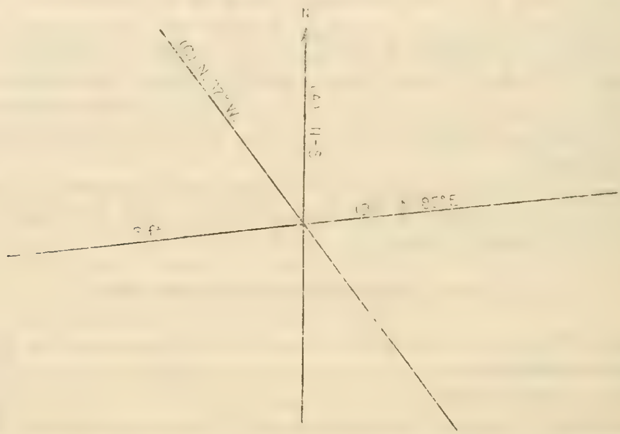

Figure 60.—Structure at Hurricane Island quarry, Knox County, Maine.

LINCOLN COUNTY.

BRISTOL.

The **Round Pond quarry** ("black granite") is in the town of Bristol, one-fourth mile east of Round Pond village, and west of Muscongus Island. Operators, Peter Svensen & Co., Round Pond. Quarry idle in 1916.

The rock (specimens D, XXVII, 126 a, 126 b) is a quartz diorite of very dark-gray and medium-gray shades and of fine, even-grained texture, with feldspars up to 0.2 inch. The darker variety consists, in descending order of abundance, of bluish-white soda-lime feldspar (oligoclase-andesine), clear quartz, black mica (biotite), potash feldspar (orthoclase and microcline), and magnetite, together with accessory titanite, zircon, and apatite and secondary calcite. The lighter variety consists of the same minerals, but with less biotite, so that it changes place with the potash feldspar in order of abundance. Both varieties take a fine polish and offer a very marked contrast between the polished and cut or hammered surface. Granite of the same shade affords no such contrast.

The quarry, opened in 1885, consists of two adjacent openings along a northwest-southeast line. The upper, or northwestern one, was in 1905 100 feet square; the lower, 400 feet northwest-southeast by 100 feet across, but with a central

[93] Smithsonian Inst. Ann. Rept., 1889, pt. 2, p. 415.

part 37 feet wide on each side—that is, 175 feet wide. These openings ranged in depth from 10 to 65 feet.

Rock structure: Considerable scientific interest attaches to the geologic relations at this quarry, as may be seen by the references to them on pages 48, 52. This quarry has been described by J. E. Wolff.[94] The diorite underlies a mass of schist which strikes N. 15° E. and is traversed by dikes and lenses of coarse pegmatite. It also includes a tongue of this schist and is traversed by dikes of pegmatite, and itself in turn is traversed, as is also its pegmatite, by a diabase dike. (See Pl. VIII, *B*). Thus the schists are older than the diorite, and the dike is later than the diorite and its pegmatite. The joint and dike courses are shown in figure 61. The sheets, 1 to 12 feet thick, dip 10° S. and also 10° E. and are traversed by joints (A), which recur at intervals of 5 to 42 feet, and (B), which recur but once or twice. There are bad headings on the northeast side of the quarry. The pegmatite dikes send out small branches. Sap, only 1 inch thick, occurs along the sheets. Knots up to 6 by 2 inches are

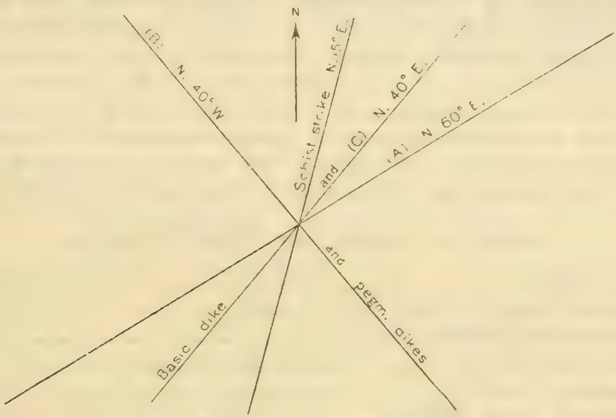

FIGURE 61.—Structure at Round Pond diorite quarry, Bristol, Maine.

rare. The general result of this complex structure is that it is difficult to obtain many large blocks.

Transportation, by cart about 300 feet from lower quarry and 800 to 1,000 feet from upper one to wharf in Muscongus Bay.

The product is used mostly for small monuments, which are shipped to New York without the lettering. (See Pl. XXII, *A*). The waste goes into paving blocks. Specimen monuments: Die of Maine monument at Andersonville, Ga.; base and die of General Sheridan monument in National Cemetery at Arlington, Va.

WALDOBORO.

The **Waldoboro quarry** is in the town of Waldoboro, 1½ miles north of Waldoboro village, on the Boston & Maine Railroad. Operator, Booth Bros. & Hurricane Isle Granite Co., 208 Broadway, New York. Quarry abandoned.

The granite (specimen D, XXVII, 109, a) is a muscovite-biotite granite of medium-gray shade (a trifle darker than "Hallowell granite" and still darker than "North Jay granite") and of fine, inclining to medium, even-grained texture, some of the feldspars measuring up to 0.25 inch, but the particles generally ranging from 0.36 to 2.56 millimeters in diameter. It consists, in

[94] Details of Maine granite quarries: Tenth Census, vol. 10, p. 121, 1888.

descending order of abundance, of a whitish translucent potash feldspar (orthoclase and microcline), smoky quartz, whitish soda-lime feldspar (oligoclase), white mica (muscovite), and black mica (biotite), with accessory garnet. Many of the feldspars are intergrown with quartz in particles circular in cross section. Some of the mica plates are bent, indicating slight (secondary) motion. E. C. Sullivan, of this Survey, finds that this granite contains 0.045 per cent of CO_2 (carbon dioxide) corresponding to a content of 0.10 per cent of $CaCO_3$ (calcium carbonate), and that warm dilute acetic acid extracts from it 0.11 per cent of CaO (lime). This granite contains sporadic particles or crystals, up to 0.25 or even 0.5 inch in diameter, of a milk-white mineral, which weathers readily, becoming yellowish and powdery, and finally leaves cavities. George P. Merrill, head curator of geology at the United States National Museum, finds it to be a feldspar lying between albite and oligoclase—that is, containing between 6 and 11 per cent of soda, therefore a little more soda than the soda-lime feldspar of the granite itself, which is 5 to 5.5 per cent—and says that the powdery material is very near kaolin. But he does not regard his results as perfectly satisfactory, nor does he understand why such a feldspar should weather so readily. The slightly higher percentage of soda indicated does not seem to him an adequate cause for the weathering, although minerals rich in soda weather with comparative facility. Workmen report that when first decomposing this mineral protrudes beyond the granite surface.

The following analysis of the granite was made by Ricketts & Banks, of New York, for the firm (No. 16074), and is given merely for reference:

Analysis of granite from Waldoboro quarry.

Silica (SiO_2)	73.48
Alumina (Al_2O_3)	15.26
Ferrous oxide (FeO)	1.42
Lime (CaO)	.88
Magnesia (MgO)	.09
Manganese oxide (MnO)	.10
Soda (Na_2O)	3.12
Potash (K_2O)	5.66
Sulphur (S) total	Trace.
Carbon dioxide (CO_2)	None.
	100.01

A test (No. 1714) of compressive strength of "Waldoboro granite" made by Prof. Ira H. Woolson, of the Columbia University School of Mines,[95] shows a crushing strength of 23,111 pounds to the square inch.

The quarry, opened in 1860, measured in 1905 400 feet N. 52° E. to S. 52° W, by 140 feet across, and was 60 to 85 feet deep.

Rock structure: The geologic relations at this quarry are of no little interest, as will be seen by the references to it on pages 48 and 91. The granite is in contact with the schist mass, which originally covered it and which at all the other Maine quarries, except those at Freeport and Round Pond, has been removed. On the northeast side of the quarry a mass of schist striking N. 72° W. and dipping 45° N. 28° E. and also 90° overlies the granite which sends small dikes into it. The contact between the two rocks as it appears at the east corner of the quarry is shown in Plate XVII, *A*. At the southwest end of the quarry two schist masses are partly included in the granite, and a large peg-

[95] Day, W. C., U. S. Geol. Survey Twentieth Ann. Rept., pt. 6, continued, p. 391, 1899.

matite mass intervenes, as is shown roughly in figure 16. The sheets, 1 to 7 feet thick, lie mainly horizontal but dip 5° W. in the upper part of the quarry. The joint and dike courses are shown in figure 62. Joints (A) dip 60° SE. and form both longitudinal walls of the quarry, a heading on the northwest side, and recur at intervals of 40 feet. Joints (B) dip 85° N. and recur at intervals of 100 feet. The rift is horizontal and the grain vertical, with strike N. 60° W. Pegmatite dike (*a*) is 5½ inches thick; dike (*b*) is 12 inches thick. Sap is confined to the upper sheets. Knots are very exceptional.

That the granite is under compressive strain is shown by the closing up of the channels when the cores are taken out, and also by spontaneous north to south fissuring.

Transportation, by cart 1,300 feet (and 120 feet down) from quarry to mill, thence by cars 19 miles to wharf at Rockland. The distance from the quarry to tidewater at Waldoboro is only 1½ miles, but the water there is only 11 feet deep at high tide.

The product is used for buildings and monuments but not for polished work. The small sheets and waste are used for paving and road ballast.

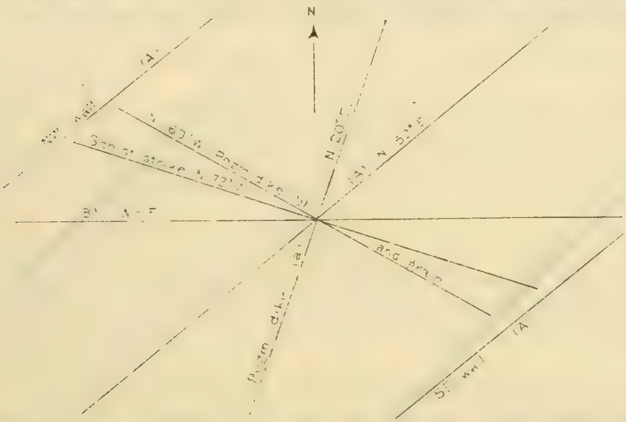

FIGURE 62.—General structure at Waldoboro quarry, Waldoboro, Maine.

About 250,000 paving blocks were shipped annually, mostly to Philadelphia. Specimen buildings: Buffalo Savings Bank; Armory, boat house, and cadets' quarters at United States Naval Academy, Annapolis, Md.; Crockett monument at Acorn Cemetery, Rockland, Maine; Chemical National Bank, "platforms" for sidewalk around Schwab Building, and Riverside Drive, New York.

This quarry was not operated in 1916.

WHITEFIELD.

Jewett's quarry ("black granite") is in the town of Whitefield, 1½ miles southeast of Whitefield village (Kings Mills). Quarry abandoned.

The rock (specimen D, XXVII, 113, a) is a quartz diorite of very dark gray shade with a bluish tinge, and of fine to medium, even-grained texture and flow structure, with feldspars up to 0.25 inch in diameter. It consists, in descending order of abundance, of bluish milk-white soda-lime feldspar (oligoclase-andesine), black hornblende, quartz in amount almost if not quite equal to that of the hornblende, black mica (biotite), and accessory magnetite, titanite, zircon, apatite, and secondary epidote. The stone takes a fair polish.

The quarry, opened in 1885 for monumental work, consists of two adjacent openings, one 50 by 25 feet, the other 60 by 30 feet. In 1905 these were 6 and 8 feet deep, respectively.

Rock structure: The sheets, 3 to 8 feet thick, dip 25°–30° NE. Vertical or steep joints strike N. 10° W. and N. 42° W. The rift is vertical, with N. 10° W. course, and the grain is parallel to the sheets. The sap is 3 inches thick along the joints. There is one aplite dike up to 4 inches thick. Biotite knots occur occasionally.

The quarry is worked only at intervals, and the stone is used for monuments locally.

OXFORD COUNTY.

FRYEBURG.

The **Eagle Gray quarry** is in the town of Fryeburg, at the northeast foot of Starks Hill, about 1¼ miles south of Fryeburg village. Operator, Eagle Gray Granite Co., Fryeburg.

The granite (specimen D, XXVII, 124, a) is a muscovite-biotite granite of medium-gray shade and of general medium, even-grained texture, with feldspar

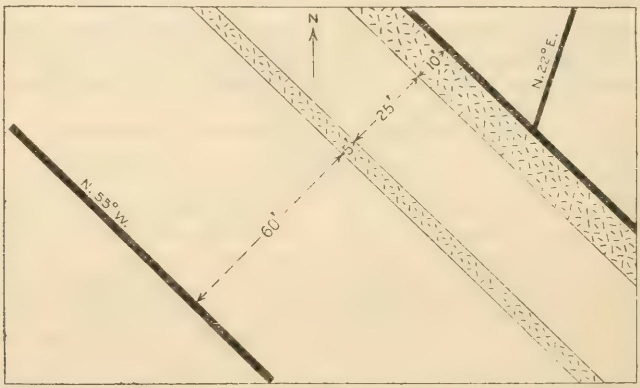

FIGURE 63.—Structure at Eagle Gray quarry, Fryeburg, Maine. The black bands are basic dikes, and those with a pattern are pegmatite.

0.25 inch in length and mica up to 0.2 inch. It consists, in descending order of abundance, of slightly cream-colored potash feldspar (orthoclase), smoky quartz, slightly cream-colored soda-lime feldspar (oligoclase), white mica (muscovite), and black mica (biotite), together with accessory garnet and zircon. The contrasts are chiefly between the cream-colored feldspar and the smoky quartz and the brilliant muscovite plates. The large size of the mica plates is unfavorable to the durability of its polish under outdoor exposure.

The quarry, opened in 1903, was in 1905 about 150 feet square by 3 to 12 feet deep.

Rock structure: The sheets, 1 to 10 feet thick and becoming thicker southwestward, dip less than 10° NE. There are no joints, but there are several pegmatite and diabase or basalt dikes, already referred to on page 52 and shown in figure 63. These generally have a northwest-southeast course. The pegmatite is very coarse, affording incomplete crystals of orthoclase 1 foot long and biotite crystals 3 inches long. Mingled with the pegmatite are irregular bands of whitish garnetiferous aplite. The absence of joints and the

abundance of dikes are the chief obstacles here. The rift is horizontal and marked, but there is no grain. Sap, 0.5 inch thick, is confined to the top sheet.

Transportation, by cart two-fifths mile to Maine Central Railroad.

The product is used for buildings and for bases to monuments. Specimen building: Granite part of the public library at Conway, N. H.

The quarry was not operated in 1916.

OXFORD.

The **Roy quarry** is in the town of Oxford, three-fourths mile from Oxford village. Idle since 1906.

The granite (specimen D, XXVII, 121, a) is a muscovite-biotite granite of medium cream-gray color and of medium, inclining to coarse, even-grained texture, with feldspars up to 0.4 inch in diameter. It consists, in approximate descending order of abundance, of a cream-colored potash feldspar (orthoclase and microcline), smoky quartz, cream-colored soda-lime feldspar (oligoclase), white mica (muscovite), and black mica (biotite), together with accessory apatite. Some of the joint planes are coated with coarse fibrous muscovite in parallel arrangement.

This quarry, opened in 1898, covers about 5 acres and has a working face 40 feet deep. It is worked only occasionally. The product is used for rough foundations and trimmings. The trimmings on the Catholic Church at Berlin, Maine, and the McGillicuddy Block at Lewiston are of this granite.

WOODSTOCK.

The **Bryant Pond quarry** is in the town of Woodstock, half a mile south of Bryant Pond station, on the east side of the Grand Trunk Railway. Operator, Grand Trunk Railway; address, Master of Bridges and Buildings, Grand Trunk Railway, Montreal, Canada.

The rock (specimen D, XXVII, 122, a) is a quartz diorite with conspicuous black particles on a bluish-white rather than a yellow-white ground, and of medium even-grained texture and flow structure, with feldspars and black minerals up to 0.3 inch in diameter (rarely 0.4). It consists, in descending order of abundance, of white translucent soda-lime feldspar (oligoclase to oligoclase-andesine), clear quartz, black mica (biotite), and black hornblende, together with accessory garnet, titanite, zircon, apatite, and a little secondary epidote. Some of the feldspars are partly altered to a white mica, and some have borders radially intergrown with quartz.[90] The clearness of the quartz and the translucent whiteness of the feldspar result in the apparent merging of the two minerals, and as the biotite and hornblende are both black the only contrast in the rock is that between black and white. There is a marked contrast between the hammered and rough surfaces, attributable to the presence of soda-lime feldspar alone. (See p. 79.) The flow structure, where marked gives the rock a gneissoid aspect.

The quarry, opened about 1864, is 150 feet from north to south by 250 feet from east to west and from 10 to 50 feet deep. It is on the west side of a north-south ridge.

Rock structure: There is a marked flow structure, in some places horizontal and parallel to the rift but in others very irregular. The sheets, 1 to 6 feet

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[90] Michel Lévy's "structure vermiculée." See Carte géol. France Bull. 36, vol. 5, pp. 27–28, fig. 5, 1894.

thick, are horizontal or slightly undulating on the quarry face, but at the west side dip 20°–30° W. They increase in thickness downward and at the bottom of the quarry appear to run out ("grow on"), making quarrying in that direction increasingly difficult. A vertical joint, striking N. 35° E., is coated with crystalline calcite and epidote. The rock adjacent to it for an inch or two contains much pyrite and also chlorite, probably derived from the alteration of hornblende. The rift is horizontal, and the grain is vertical north-south, but disappears on the west side. Vertical basalt or diabase dikes, with northeasterly courses, form the north and south walls of the quarry, 4 feet and 22 inches thick, respectively. A 5-inch dike occurs 25 feet north of the south wall. A thin section of a half-inch branchlet from this dike is described on page 52. Sap is confined to the upper sheets. There are some knots.

The product is used entirely for bridges and stations on the Grand Trunk Railway. Specimen buildings: Vestibule, first story, and trimmings of station at Portland, Maine; station at Battle Creek, Mich.

PENOBSCOT COUNTY.

HERMON.

The **Hermon Hill quarry** ("black granite") is on Hermon Hill, 5½ miles northwest of Bangor. Owner, Dr. H. F. Hanson, Bangor.

This black granite (specimen D, XXVI, 106, c) is an altered diabase porphyry of dark-green color and fine texture, with porphyritic crystals of black hornblende up to 0.75 inch in diameter. The rock consists, in descending order of abundance, of hornblende, calcite, a much altered feldspar (plagioclase), and magnetite, together with secondary actinolite, fibrous serpentine, and chlorite. It contains sufficient calcite (calcium carbonate) to make it effervesce with cold dilute hydrochloric acid. It takes a very fine polish and cuts very light, but the presence of the calcite exposes it to attack by the carbonic acid of the atmosphere. It is therefore more suitable for indoor work. Ora W. Knight,[97] State assayer of Maine, reports that it contains a very small amount of platinum which is very irregularly and unevenly distributed.

Rock structure: The outcrop is about 200 feet from northeast to southwest by 40 to 50 feet across and occurs in a chloritic quartzose shale striking N. 45° E. In places, however, there intervenes a granite porphyry containing crystals of orthoclase largely altered to muscovite, chlorite, and biotite. The sheets, from 6 inches to 6 feet thick, dip 30° S. 60° E. Vertical joints strike N. 60° W., forming a heading on the northeast, and recur at 20-foot intervals, also striking N. 20° W. and spaced from 2½ to 8 feet. Both show marks of slippage. There is also a diagonal set striking N. 45° W. and dipping 45° SW., recurring irregularly. The rift seems to be parallel to the sheets. Sap occurs along the joints. There are quartz veins parallel to the sheets and rift.

Transportation, by cart 1 mile to Maine Northern Seaport Railroad or 5½ miles to Bangor.

The quarry is worked only occasionally.

The product is used for dies, memorial tablets, and wainscoting. Specimen monuments: Die on soldiers' monument at Hermon; about 20 dies in Mount Hope and in Mount Pleasant cemeteries at Bangor; dies at cemetery at Springfield; cornerstone of Catholic Church at Orono; keystone, etc., at Lord Hall, University of Maine.

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[97] Letter addressed to Dr. Hanson Oct. 3, 1905.

PISCATAQUIS COUNTY.

GUILFORD.

The **Queen City quarry** is 3½ miles from Foxcroft, in Guilford Township. Last operator, Queen City Granite Co., Bangor. Quarry idle in 1918.

The granite (specimen D, XVII, 107, a) is a biotite-muscovite granite of light-gray shade and medium to coarse, even-grained texture, with feldspars up to 0.5 inch in diameter and biotite scales up to 0.15 inch. It consists, in descending order of abundance, of very slightly bluish-white potash feldspar (microcline), smoky quartz, a whitish soda-lime feldspar (oligoclase), black mica (biotite), and much less white mica (muscovite), together with accessory magnetite. The oligoclase is partly altered to a white mica. As the feldspars are of similar color and the muscovite is present in small amount the contrasts are between the feldspar, smoky quartz, and biotite, and they are marked.

The quarry measured in 1905 100 by 50 feet, with a maximum depth of 70 feet, averaging about 35.

The stone was used for building. The trimmings of a brick building erected in 1899 for the Bangor Theological Seminary and those of the Stetson Block at Bangor are made of it.

The **Brawn quarry** is 1 mile distant from the Queen City, in the same township. Operator, H. A. Brown, Foxcroft. The granite resembles that of the Queen City quarry. Quarry temporarily idle in 1918.

SOMERSET COUNTY.

HARTLAND.

The **Hartland quarry** is in the town of Hartland, near Hartland village, on the Sebasticook & Moosehead Railroad. The quarry, prior to 1905, had been operated by Joseph H. Baker. Property reported as owned by the Linn estate.

The rock (specimen D, XXVII, 141, a, collected by Dr. George Otis Smith), is a quartz diorite with conspicuous black particles on a more bluish than yellowish-white ground, of medium to coarse, even-grained texture with flow structure. It consists, in descending order of abundance, of a translucent milk-white soda-lime feldspar (oligoclase), very slightly smoky quartz, black mica (biotite), black hornblende, and accessory titanite and magnetite. Some of the feldspars are cloudy from incipient alteration.

NORRIDGEWOCK.

The **Dodlin quarry** is in the town of Norridgewock, on the northeast side of Dodlin Hill, 2½ miles south of Norridgewock village, and has a north-northeasterly axis and a height of 350 feet above the general level and of 650 feet above the sea. Although this quarry is now disused, it is described because of its geologic interest.

The rock (specimens D. XXVII, 116, a, 116, b) is a quartz monzonite of two shades. Specimen 116, a, is a general medium gray with conspicuous black particles on a white ground; and specimen 116, b, is a general light gray with much finer black particles on a ground of mixed white and gray. Both rocks have a like texture, medium inclining to fine, with porphyritic crystals of white feldspar up to 0.5 inch. In the darker rock (116, a) the biotite scales measure up to 0.1 inch; in the lighter rock they rarely attain 0.05 inch. Both varieties consist, in descending order of abundance, of a slightly bluish milk-white soda feldspar (oligoclase) and, in equal or slightly less amount, a

whitish potash feldspar (microcline); quartz, almost clear in the darker rock (116, a) and light smoky in the lighter one (116, b); and black mica (biotite) (considerable in 116, a, but much less in 116, b), with accessory magnetite, titanite, zircon, and pyrite, and secondary epidote and white micas. Some of the feldspars are radially intergrown with quartz.

The quarry, opened about 1885, measured in 1905 400 feet from north-northwest to south-southeast by 250 feet across, with an average depth of 30 feet.

Rock structure: There is a vertical northeast-southwest flow structure indicated by the dividing line between the dark and light granite (shown in fig. 64), and also in the light and dark banding of some of the lower sheets. The sheets, 2 inches to 16 feet thick, dip about 5° E. In the southern part of the quarry they are up to 2 feet thick, but in the northern part 2 to 16 feet. The joints are parallel to the flow and spaced 200 feet. From the relation of the thickness of the sheets to the joint spaces, both in this quarry and in two adjacent openings, it appears that in places thin sheets, in others thick sheets, continue downward in alternating vertical zones, and that thin sheets are also likely to occur on both sides of the vertical joints for a few feet. These exceptional relations are probably due to vertical faulting. A small horizontal displacement in a vertical flowage band is evidently due to faulting at right angles to the other. The rift is horizontal, at right angles to the flow. The grain is vertical and parallel to flow and jointing. "Shake" structure occurs along the sheets near headings. (See p. 39.)

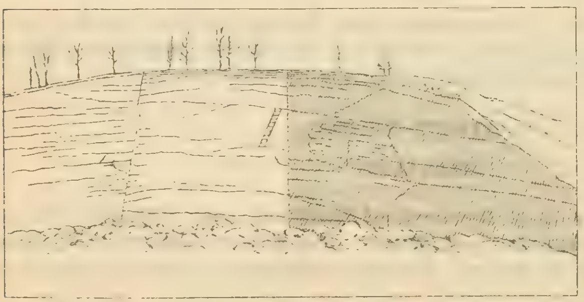


FIGURE 64.—Diagrammatic sketch showing junction of light and medium-gray granites (quartz monzonites) and the lateral change in thickness of sheets at the Dodlin quarry, near Norridgewock, Maine.

The product was used mainly for buildings. Specimens: Post office, Muskegon, Mich.; Merrill Library, Norwood, Mass.; Catholic Church, Lewiston, Maine; courthouse, Bangor, Maine; insane asylum (annex), Augusta, Maine.

The **Lawton quarry** is in the town of Norridgewock, on the northwest side of Dodlin Hill, 2½ miles south-southwest of Norridgewock. Operator, F. S. Lawton, Norridgewock. Idle since 1917.

The rock is a quartz monzonite of medium-gray and light-gray shade and medium and porphyritic texture, identical with that of the Dodlin quarry.

The quarry, opened before 1845, consisted in 1905 of two openings measuring 200 by 100 and 300 by 200 feet and 5 to 10 feet deep.

Rock structure: The same flow structure occurs as at the Dodlin quarry, on the other side of the hill. The sheets, up to 5 feet thick, average 3 to 4 feet and roll over the hill with a dip of 10° both north and south. Between some of the ordinary sheets there are unusual ones, 0.5 inch thick, which in large slabs are flexible. Whether this was in part due to incipient disintegration was not determined. The lenticular form of the sheets gives them the appearance of being very irregular in thickness. Vertical joints, strike N. 60°–65° E., recur at intervals of 10 to 50 feet. The rift is horizontal, and the

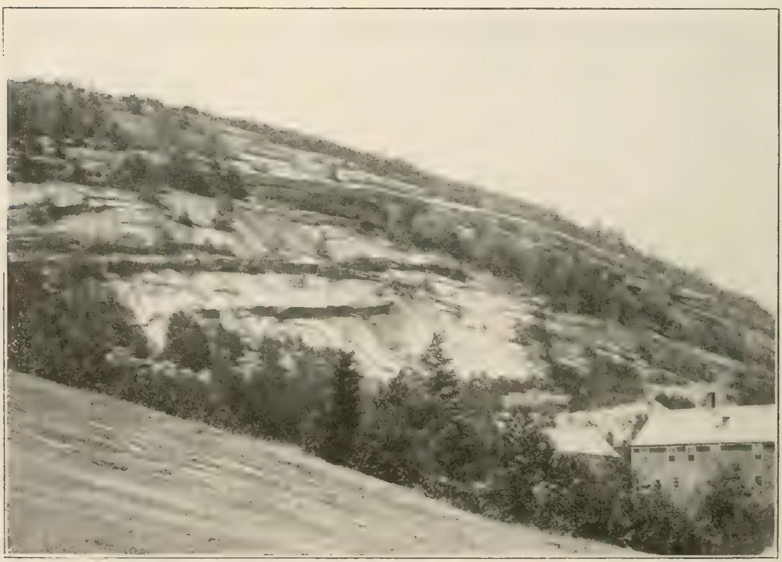
A. EAST-WEST JOINTS IN GRANITE ON HERON NECK, AT SOUTH END OF GREEN ISLAND, EAST OF VINALHAVEN, MAINE, LOOKING FROM HURRICANE ISLAND.

B. SOUTH HALF OF CROTCH ISLAND, STONINGTON, MAINE, LOOKING WEST FROM ROCK ISLAND.

Showing concentric sheet structure crossed by vertical east-west joints. Goss quarry at left; Ryan-Parker quarry at right.

A. SHEET STRUCTURE AT RYAN-PARKER QUARRY ON CROTCH ISLAND, MAINE, LOOKING SOUTHWEST.

The lower sheet is 25 feet thick and is split along the rift.

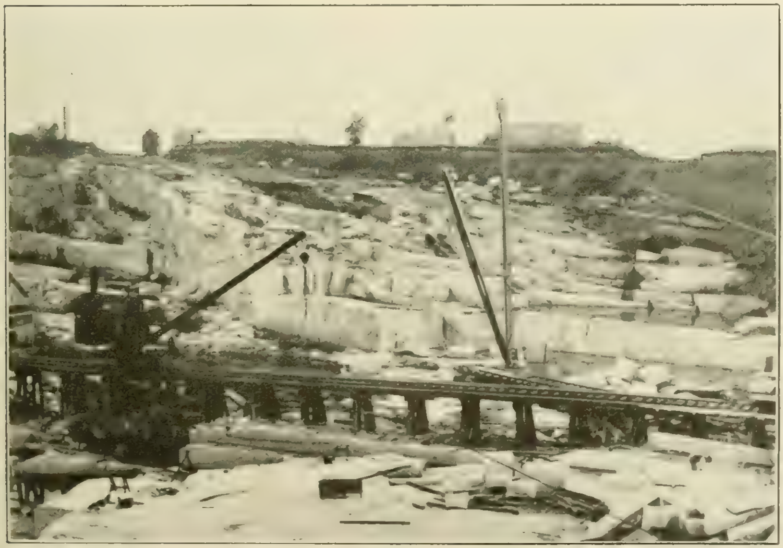


B. EAST SIDE OF MOSQUITO MOUNTAIN, FRANKFORT, MAINE, LOOKING NORTHWEST.

Showing sheet and dome structure, also erosion of sheets.

A. HURRICANE ISLE QUARRY, MAINE, EAST END.

Showing lower 60-foot sheet overlain by 20-foot sheet and crossed by vertical east-west joint and by diagonal joint.



B. STINCHFIELD QUARRY, HALLOWELL, MAINE, LOOKING WEST-NORTHWEST.

Showing sheets increasing in thickness downward, crossed by joint C and overlain by glacial drift.

A. SHEET STRUCTURE ON SOUTH SIDE OF CRABTREE & HAVEY QUARRY, SULLIVAN, MAINE.

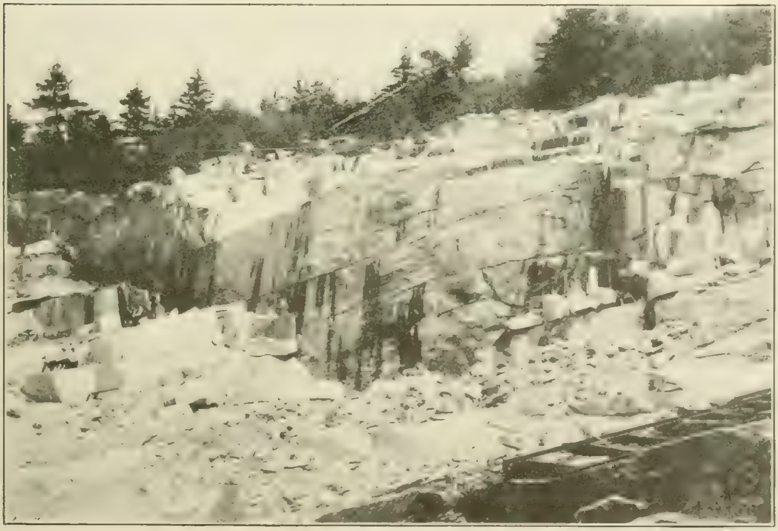
The cuts are along the grain and "hard way" and show nine black segregations or "knots."

B. EAST WALL OF CRABTREE & HAVEY QUARRY, SHOWING LENTICULAR FORM OF SHEETS IN VERTICAL CROSS SECTION ON A JOINT FACE.

The form of these sheets accounts for the irregularity of thickness shown in *A*.

A. SANDS QUARRY, VINALHAVEN, MAINE, LOOKING S. 80° E.

Showing curvature of the sheets, an intersecting joint face, and the channeling along the "hard way," or N. 10° E.



B. WHITE QUARRY, BLUEHILL, MAINE, LOOKING N. 10° W.

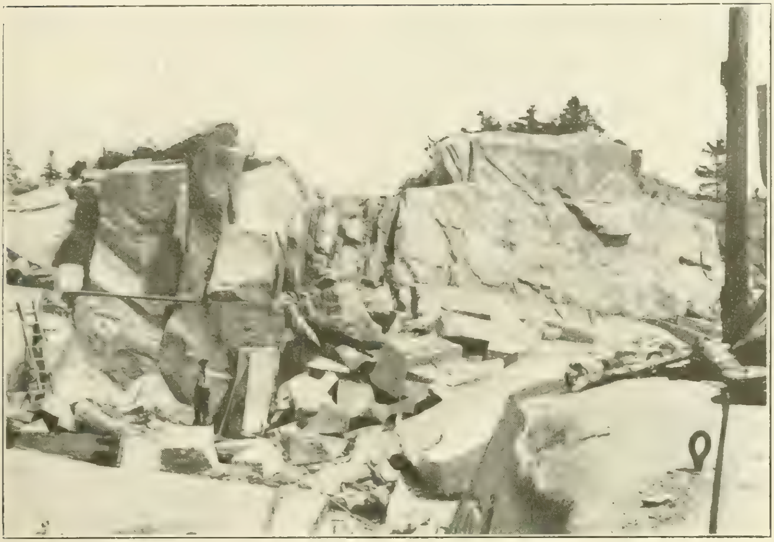
Showing lenticular sheets crossed by a vertical joint curving from N. 50° W. to N. 50° E. The black vertical streaks are underground water issuing from between the sheets.

A. EFFECT OF COMPRESSIVE STRAIN ON THIN SHEET OF GRANITE GNEISS, ROCK CHAPEL HILL, LITHONIA, GA.

Width of arch, 14 feet; height, 9 inches. Photograph by G. K. Gilbert, U. S. Geol. Survey.

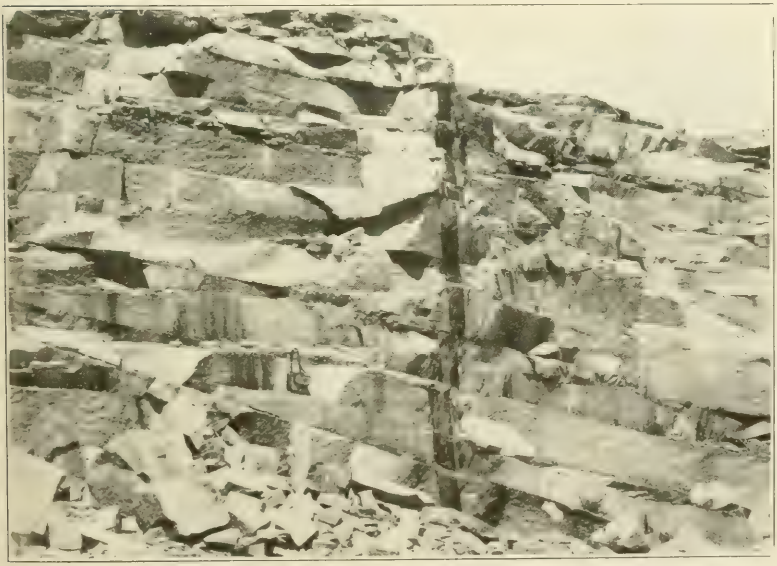
B. LOWER EDGE OF SCHIST INCLUSION IN GRANITE AT QUARRY IN FREEPORT, MAINE.

Showing ragged edge of partly detached piece of the biotite schist, also smaller fragments. The black streak on the granite is rusty stain from the schist.



A. HIGH ISLE QUARRY, MUSCLE RIDGE PLANTATION, MAINE, LOOKING EAST.

Showing sheets crossed by a N. 75° W. heading.



B. ALLEN QUARRY, WEST SIDE OF SOMES SOUND, MOUNT DESERT, MAINE, LOOKING N. 15° W.

Showing thin lenticular sheets crossed by small vertical diabase dike faulted on fourth sheet from bottom, with a displacement of 16 inches along the sheet.

A. EAST CORNER OF WALDOBORO QUARRY, WALDOBORO, MAINE.

Showing contact between granite with horizontal sheets and schist strata dipping east-northeast.

B. NORTHWEST WALL OF LONGFELLOW QUARRY, HALLOWELL, MAINE.

Showing intersection of two headings, one striking N. 45° W., the other N. 65° E.; also the progressive concentric rusty discoloration from sheet and joint surfaces.

A. WEBSTER QUARRY, ON PLEASANT RIVER AT END OF WINTER HARBOR, VINALHAVEN, MAINE, LOOKING WEST.

A typical tidewater quarry. Granite-laden schooner at right. Photograph by Merrithew.

B. A TYPICAL MAINE PAVING-BLOCK QUARRY, CALLED A "MOTION."

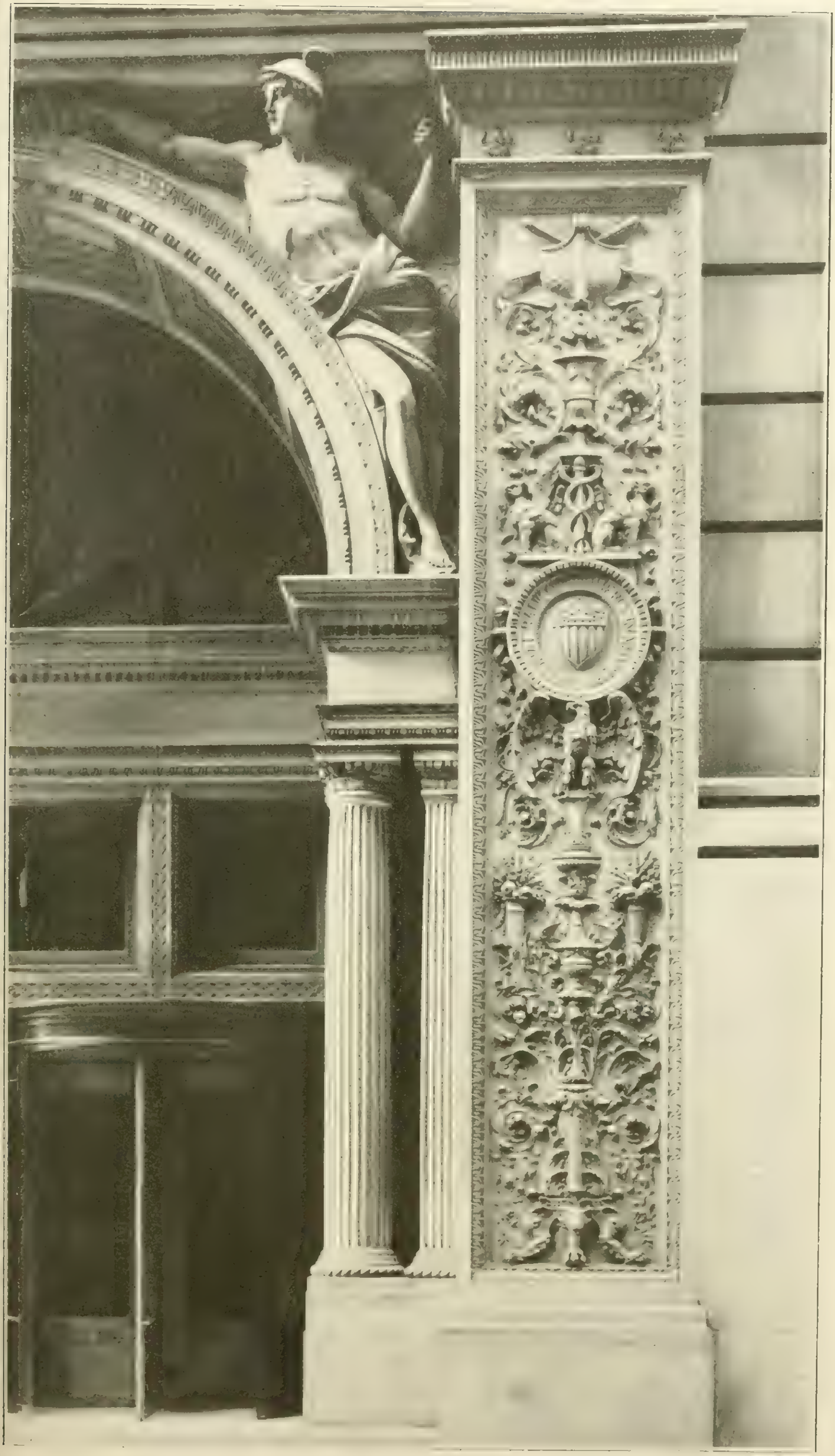
Operated by one man provided with a tent, rarely with very small hand derrick. Photograph by Merrithew.

A. LINTEL FOR NEW YORK CUSTOMHOUSE.

Carved of coarse biotite granite from the Sands quarry, Vinalhaven, Maine. Left part unfinished. Photograph by Merrithew.

B. MONOLITHIC COLUMNS FOR THE CATHEDRAL OF ST. JOHN THE DIVINE AT NEW YORK.

Coarse biotite granite from Palmer quarry, Vinalhaven, Maine. Length, 51 feet 6 inches; diameter, 6 feet. One column in lathe.



PANEL AT ENTRANCE OF NEW YORK BANK OF COMMERCE.

Carved of fine biotite-muscovite granite from Stinchfield quarry, Hallowell, Maine.

STATUE AT HALL OF RECORDS, NEW YORK.

Fine biotite-muscovite granite from Stinchfield quarry, Hallowell, Maine.

A. MONUMENT OF QUARTZ DIORITE FROM ROUND POND QUARRY, MAINE, READY FOR SHIPMENT.

Showing contrast between cut and polished faces.

B. MONUMENT WITH DIE OF OLIVINE NORITE FROM HEAL QUARRY, LINCOLN, MAINE.

Showing contrast between polished face and cut lettering.

grain vertical, with course N. 60° E. Knots, both light and dark, are rare. Sap occurs along the sheets up to 6 inches in thickness. A 6-inch dike of white aplite strikes N. 80° W., glaciated with the granite at the surface (specimen D, XXVII, 116½, c).

Transportation, by cart 3 miles to railroad at Norridgewock.

The product is used for buildings, bridges, and monuments to supply local demands. Specimen: Town bridge at Bingham, Maine.

The **Taylor quarry** is in the town of Norridgewock, on Dodlin Hill, about one-fourth mile north of the Lawton quarry. Operators, D. E. Taylor & Son, Norridgewock. Idle since 1916.

The granite (specimen, D, XXVII, 117, a) is a biotite-muscovite granite of light-gray shade and very fine, even-grained texture. The particles range from 0.11 to 1.1 millimeters, exceptionally 2.19 millimeters, and average about 0.50 millimeter. They consist, in descending order of abundance, of a slightly bluish milk-white potash feldspar (microcline and orthoclase), clear quartz, soda-lime feldspar (oligoclase), black mica (biotite), and very little white mica (muscovite), together with accessory magnetite and apatite.

This is a small opening, from which stone is obtained occasionally for monumental purposes.

WALDO COUNTY.

FRANKFORT.

The **Mosquito Mountain quarry** is in the town of Frankfort, on top of Mosquito Mountain, 2 miles S. 10° E. of Frankfort village. This mountain is a granite dome rising 545 feet above tidewater, close by, with a steep east face shown in Plate XI, *B*. Operator, 1905, Hayward Pierce, Frankfort. Quarry not operated since 1912 and now abandoned.

The granite (specimen D, XXVI, 52, a) is a hornblende-biotite granite of general medium-gray shade and of porphyritic texture, with milk-white feldspar crystals from 0.5 inch to 1.5 inches in diameter in a gray matrix of medium texture, with black minerals up to 0.1 inch. It consists, in descending order of abundance, of milk-white potash feldspar (orthoclase and microcline), smoky quartz, milk-white soda-lime feldspar (oligoclase), black hornblende, and black mica (biotite), together with accessory titanite, magnetite, and apatite, and a little secondary chlorite, epidote, and carbonate (calcite or dolomite). The porphyritic feldspars are generally twins. E. C. Sullivan, of the United States Geological Survey, finds that this granite contains 0.1 per cent of CO_2 (carbon dioxide) and that warm dilute acetic acid extracts 0.07 per cent of CaO (lime) and a trace of MgO (magnesia). Figuring the CO_2 to both CaO and MgO this would give 0.13 per cent of $CaCO_3$ (calcium carbonate) and 0.08 per cent of $MgCO_3$ (magnesium carbonate). The microscope also shows carbonate.

A test of the compressive strength made of this granite in connection with its use for the U. S. dry docks at Kittery, Maine, reported by the owner of the quarry, gives it an ultimate crushing strength of 32,635 pounds to the square inch.

The quarry was opened before 1837 on the east side of the mountain. The later opening on the top measured in 1905 1,000 by 500 feet, with a maximum depth of 25 feet.

Rock structure: The sheets, 6 inches to 15 feet thick, dip gently northwest and east from the summit of the dome, and below, on the east side, they dip 45°, as shown in Plate XI, *B*. Some of the upper sheets taper out at the sides.

(See, further, p. 31.) Vertical joint and dike courses are shown in figure 65. The rift is horizontal, and the grain is vertical, with strike N. 80°–85° W. Some of the joint surfaces are coated with secondary chlorite and pyrite. A dike of quartz monzonite, 10 feet thick, dips 40° E. (See p. 41.) There are branching dikes of aplite from 1 to 3 feet thick. At the south end of the quarry a diabase dike 7 feet thick crosses from east to west. (See p. 52.) Somewhat abundant knots up to a foot in diameter and of circular or elliptical cross section occur. Sap is up to a foot thick in the upper sheets but absent lower down.

Transportation, by about 7,000 feet of track and gravity cars from quarry to cutting shed and wharf on Marsh River (South Branch Stream), which admits schooners of 14-foot draft.

The product was used for bridges and buildings, and the small sheets and waste for paving. Specimens: Post office at Lynn, Mass., and part of that at Chicago, Ill.; New York Central Railroad bridge across Harlem River.

The **Mount Waldo quarry** is in the town of Frankfort, on the north spur of Mount Waldo, 660 feet above sea level, one-third mile southwest of Frankfort village. The geographic relations of Mosquito Mountain and Mount Waldo

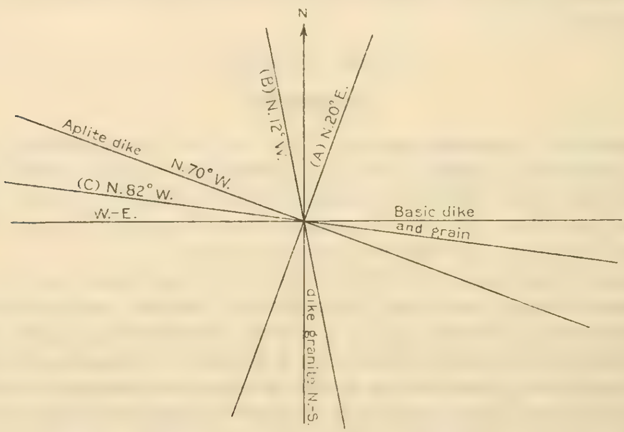


FIGURE 65.—Structure at the Mosquito Mountain quarry, Frankfort, Maine.

to Penobscot River are shown on the U. S. Geological Survey's Bucksport topographic map. This quarry was operated by the Mount Waldo Granite Works, Frankfort, but has been idle since 1914.

The granite (specimen D, XXVI, 53, a) is a biotite granite of medium-gray shade and fine even-grained texture, with feldspar up to 0.2 inch and biotite scales up to 0.1 inch. The finer particles range from 0.36 to 1.46 millimeters in diameter. It consists, in descending order of abundance, of gray potash feldspar (orthoclase and microcline), smoky quartz, gray soda-lime feldspar (oligoclase), and black mica (biotite), together with accessory magnetite, titanite, and secondary chlorite. The oligoclase is partly altered to kaolin and a white mica. A coarser and lighter granite (specimen 53, b) from this quarry is a biotite granite of light-gray shade and medium, inclining to fine, even-grained texture, with feldspars up to 0.3 inch and biotite scales up to 0.1 inch, consisting, in descending order of abundance, of white potash feldspar (orthoclase and microcline), smoky quartz, white soda-lime feldspar (oligoclase), and black mica (biotite), together with accessory magnetite, titanite, and secondary chlorite. The oligoclase is partly altered to kaolin and a white mica. This

variety is in places coarsely porphyritic. George P. Merrill[98] refers to the two "Mount Waldo granites." A test of the compressive strength of Mount Waldo granite, made at the United States arsenal at Watertown, Mass., in 1900,[99] yielded the following results with 2-inch cubes:

Test of Mount Waldo granite.

No. of test.	Direction of pressure.	Specific gravity.	First crack.	Total pressure applied.	Ultimate strength per square inch.
			Pounds.	*Pounds.*	*Pounds.*
11055	At 90° to rift	2,637	120,000	128,400	31,782
11056	do	2.655	123,300	132,500	32,635
11057	Parallel to rift	2,662	107,400	122,600	30,197
11058	do	2.649	112,600	117,900	29,183

The quarry, opened before 1851, measured in 1905 800 feet from north to south by 400 feet from east to west and from 10 to 30 feet in depth.

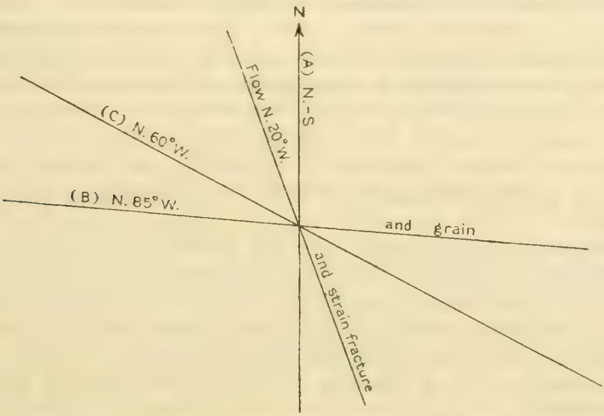


FIGURE 66.—Structure at the Mount Waldo quarry, Frankfort, Maine.

Rock structure: There is a vertical dike of the coarser and lighter granite (specimen 53, b) 200 feet or more wide, having a course N. 20° W., with the darker granite (specimen 53, a) on both sides of it, the relations indicating vertical flow structure. The longer axes of many of the feldspars lie about north-south. The sheets, 8 inches to 8 feet thick and lenticular, dip 10° E. The joint courses are shown in figure 66. There is only one joint of (A). (B) recurs at intervals of 40 feet; (C) at intervals of 20 to 40 feet or more. The rift is horizontal, and the grain vertical, striking N. 85° W. The granite is under compressive strain from east-northeast to west-southwest, causing north-northwest to south-southeast vertical fissures the entire length of the quarry. This fissuring has occurred in summer time and has been accompanied by an explosive noise. The sheets are very free from sap. Knots are exceptional, but one near the junction of the fine and medium granites measures 6 by 3 feet and consists of a medium gray aplite, with porphyritic

[98] Collection of building and ornamental stones in the United States National Museum: Smithsonian Inst. Ann. Rept., 1889, pt. 2, p. 415.

[99] Reilly, J. W., Ordnance Dept., Tests of Metal, etc., 1900, p. 110, 1901.

whitish twinned feldspars up to 0.75 inch in length and biotite scales up to 0.05 inch.

Transportation, by two graded tracks, each 1,200 feet long, operated by gravity from the quarry part way down the hill to the power house, thence by a cable road (Roebling engine) 1¼ miles to the wharf, which is accessible to schooners of 15-feet draft.

The product is used for buildings. The small sheets and waste are made into paving blocks. Specimen buildings: Milwaukee, Cleveland, Indianapolis, and Jersey City post offices; Philadelphia Mint; new municipal building, New York; Public library, St. Louis; post office, Bangor, Maine.

LINCOLN.

The **Lincolnville quarry** is in the town of Lincoln, near the north end of Lake Megunticook. Operator, W. E. Dornan, East Union.

The granite (specimen D, XXVI, 50, a) is a muscovite-biotite granite of light-gray shade and fine, inclining to medium, even-grained texture, with feldspars up to 0.2 inch, muscovite to 0.15 inch, and biotite to 0.1 inch. The finer particles range from 0.18 to 1.83 millimeters in diameter. The rock consists, in descending order of abundance, of slightly bluish-white potash feldspar (orthoclase and microcline), smoky quartz, whitish soda-lime feldspar (oligoclase), white mica (muscovite), and black mica (biotite), together with accessory apatite. The oligoclase is much altered to kaolin. The feldspars generally are intergrown with quartz in particles that are circular in cross section. The stone takes a fair polish with a bluish tinge, but the size of the muscovite plates is against the great durability of the polish under outdoor exposure.

The quarry opened about 1875, measured in 1905 100 by 50 feet and was 28 feet deep.

Rock structure: The sheets, 6 to 15 feet thick, dip 25° S. Vertical joints, strike N. 60°–65° W., recur at intervals of 8, 14, and 23 feet; also a single joint, strike N. 60°–65° E. Another one strikes N. 60° W. and dips 60° SE. The rift is vertical, with strike N. 60°–65° W. Sap is faint and 4 to 8 inches thick along the sheets. Knots, up to 8 by 0.5 inch, are rare.

Transportation, by cart 5 miles to electric railroad, thence 8 miles to Maine Central Railroad.

The product is used locally almost entirely for monuments. Specimen: Trimmings to Carlton Block, Rockport, Maine.

The **Heal quarry** ("black granite") is in the town of Lincoln, about 2 miles from the bridge over the outlet to Tilden Pond and about 3½ miles from the shore of Penobscot Bay. Operator, A. S. Heal, Belfast. Quarry abandoned.

This rock is an olivine norite of almost black shade, with glistening surfaces, and of medium texture. The polished surfaces show a brilliant dark olive-greenish mineral. Under the microscope this rock consists of interlacing slender crystals of a translucent lime-soda feldspar (labradorite, with 10 to 14 per cent of lime), the spaces between which have been filled with the following minerals, in descending order of abundance: Greenish hypersthene (see p. 94), black hornblende, greenish olivine, black mica (biotite), and magnetite, with accessory pyrite and secondary chlorite and serpentine. The stone takes a brilliant polish and under sunlight shows the greenish hypersthene. The hammered or cut surface is very light, as shown in Plate XXII, *B*.

The quarry, opened in 1903, measured in 1905 30 by 40 feet and about 10 feet in depth. It is worked only occasionally. The stone has to be carted 7 miles to Belfast to be cut. It is used for dies and tablets for local demand and is admirably adapted for these purposes.

SEARSPORT.

The **Bog Hill quarry** is in the town of Searsport, on Mount Ephraim (Bog Hill), about 5 miles north-northwest of Searsport village and 2 miles east of Swanville.

The granite (specimen D, XXVI, 51, a) is a biotite granite of light-gray shade and porphyritic texture, with feldspars up to 1.5 inches in diameter, in a groundmass of medium texture, with biotite scales up to 0.2 inch. It consists, in descending order of abundance, of a whitish potash feldspar (orthoclase and microcline), smoky quartz, whitish soda-lime feldspar (oligoclase), and black mica (biotite), together with accessory magnetite, titanite, zircon, apatite, and secondary chlorite and epidote. The porphyritic orthoclase crystals, generally twinned, are intergrown with oligoclase and quartz. Some have a zonal structure indicated by inclusions of quartz and oligoclase. The oligoclase is partly altered to kaolin and a white mica.

The quarry is 200 feet from north to south by 50 feet from east to west and averages about 5 feet in depth.

Rock structure: The sheets, 1 to 4 feet thick, dip 10° S. 30° E., and are crossed by steep joints striking N. 75° W., forming headings at the south side, and one in the center. Some black knots up to 2 inches across; also pyrite crystals on the joint faces.

This stone has been used for monuments and buildings in Belfast and for paving blocks, but the quarry is abandoned. The product had to be carted 5 miles to Searsport.

SWANVILLE.

The **Oak Hill quarry** is in the town of Swanville, on Oak Hill, about 6 miles north-northwest of Belfast. Quarry abandoned.

The granite (specimen D, XXVI, 49, a) is a biotite granite of slightly bluish dark-gray color and fine even-grained texture, with particles ranging generally from 0.25 to 1 millimeter in diameter and an occasional feldspar up to 2.5 millimeters or 0.1 inch. It consists, in descending order of abundance, of slightly bluish-white potash feldspar (microcline and orthoclase), smoky quartz, slightly bluish-white soda-lime feldspar (oligoclase), and black mica (biotite). The feldspars are intergrown with quartz and the oligoclase is here and there partly altered to a white mica. The stone takes a very fine polish, to the durability of which the fineness of the mica contributes.

The quarry, opened about 1872, consists of several openings, the largest of which is 175 by 100 feet, with a working face 60 feet high.

Rock structure: The sheets, 1 to 4 feet thick, dip 10° W. Vertical or steep joints, strike N. 80° W., recur at intervals of 10 and 20 feet and form headings on the north side. Sap 2 inches thick occurs along the sheets. There are some knots up to 2 inches across.

Transportation, by cart one-fourth mile to a siding from Sargents Crossing on the Maine Central Railroad.

The product is well adapted to monumental uses. The stone is the darkest of the fine-textured granites of the State (compare Freeport, p. 211; Pownal, p. 211; and Sherwood, p. 227) and is finer textured than the blue granite of Westerly, R. I. This quarry was formerly leased to the New England Granite Co., of Westerly.

WASHINGTON COUNTY.

ADDISON.

The **Pleasant River quarry** ("black granite") is in the town of Addison at Dalotville, on the east side of Pleasant River Bay. Operator, Pleasant River Granite Co., Addison. Idle in 1921 and 1922.

This rock (specimen D, XXVI, 93, a) is an hypersthene-olivine gabbro of almost black shade and of medium ophitic texture, with black particles up to half an inch and slender whitish crystals. The polished surface is jet-black mottled with a little white. Under the microscope this rock consists, in descending order of abundance, of slender whitish transparent crystals of a feldspar (with both lime and soda, andesine-labradorite) intricately interlaced, the spaces between which are filled with a dark-brownish diallage (see p. 94), black mica (biotite), a little hypersthene, and greenish olivine, together with secondary magnetite, a white mica, and calcite. The diallage is altered along its edges to hornblende. The stone takes a very fine polish, and the hammered or cut surface is almost white. It is referred to by George P. Merrill[1] and by John E. Wolff.[2] It was reported to the company by John S. Newberry in October, 1890, as withstanding a pressure of 22,410 pounds to the square inch. Its weight is given by the firm as 184 pounds to the cubic foot.[3]

The quarry, opened about 1885, in 1905 measured 75 by 50 feet with a working face about 50 feet high. It is on the south side of an east-west ridge 70 feet high, the upper 5 to 10 feet of which consists of morainal sand and boulders.

Rock structure: The sheets, 3 to 17 feet thick, undulate from the horizontal to a dip of 10° E. Vertical joints, strike N. 80° E., recur at intervals of 5 to 10 feet and form a heading on the south; a set striking N. 35° W. recurs at intervals of 20 to 30 feet, forming a heading on the west. There are also several irregular fractures. The rift is vertical east-west, and the grain is horizontal. There are 10 feet of stained and fractured rock at the top, but sap is usually hardly an inch in thickness. Dikes of whitish quartz monzonite, described on page 61 of Bulletin 313, are 1 to 14 inches thick. There is also a more or less horizontal light and dark banding, due to alternating changes in the amount of feldspar.

Transportation, by cart on a track 300 feet from quarry to mill and 300 feet thence to wharf on Pleasant River Bay.

The product is used for monuments and interior decorations. The dimensions of the blocks are limited by the spacing of the joints and sheets. The usual sizes shipped measure 2 feet 6 inches by 2 feet 6 inches by 1 foot and also 3 to 6 feet by 1 foot by 1 foot. The largest block shipped measured 6 feet by 4 feet 6 inches by 4 feet 6 inches.

Specimen work: Base of wainscoting in the city hall at Philadelphia; tablet with Welsh inscription in Washington Monument, Washington, D. C.; Danforth monument, Morristown, N. J.; Zeller monument, Lewisburg, Pa.; Center monument, Greewood Cemetery, Brooklyn, N. Y.; mantlepiece in public library at Machias, Maine; memorial to Architect French in New York.

The **Thornberg quarry** ("black granite") is in the town of Addison, 3 miles south of Addison village. Operator in 1905, A. M. Thornberg, Addison; quarry not operated in 1916.

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[1] Tenth Census, vol. 10, p. 24, 1884.

[2] Idem, p. 116.

[3] Newberry's report will be found in U. S. Geol. Survey Eighteenth Ann. Rept., pt. 5, continued, p. 961, 1897.

The rock (specimens D, XXVI, 94, a and 94, aa) is a hypersthene gabbro of almost black shade and of medium ophitic texture. There are two varieties—a dark one, which is externally identical with that from the Pleasant River quarry, and a lighter one, in which the white mottling due to the feldspar is a little more abundant. Under the microscope this stone is generally identical with that of the Pleasant River quarry, except that in this one the feldspar is labradorite and there is no olivine. This, however, may not be characteristic of the rock as a whole. A little accessory pyrite and apatite and a good-sized particle of secondary epidote were also found in the "Thornberg" gabbro. The stone takes a very fine polish, and the hammered or cut surfaces are almost white.

The **Black Diamond quarry** ("black granite") is in the town of Addison, on Yoho Bay. Operator, Maine Black Diamond Granite Co.

The rock (specimen D, XXVI, 91, a), known as "Indian Black Diamond granite," is a hypersthene gabbro of very dark gray shade, with slight brownish tinge, and of fine to medium ophitic texture, consisting, in descending order of abundance, of a whitish soda-lime feldspar (andesine) in not greatly elongated crystals, brownish diallage (partly altered to hornblende), black mica (biotite), a little hypersthene, and quartz, together with accessory magnetite. Where most exposed the ledge has turned a little brownish and weathered spheroidally. A polished block, reported as from this quarry and shown to the writer in a stonecutter's yard at Quincy, Mass., had become pitted from exposure, but monuments erected 20 years or more ago in New York City are reported to be in good condition.

The quarry in 1902 was 200 feet square and from 10 to 20 feet deep. It has a track 600 feet long to a wharf which admits schooners of 11 feet draft. The older part of the quarry has been worked down to sea level, but a large supply of stone lies to the east in a rising ridge.

Rock structure: The sheets, 3 to 8 feet thick, are horizontal or dip 20° N. Vertical joints, strike N. 80° E., recur at intervals of 5 to 20 feet, and a set striking N. 30° W. recurs at intervals of 2 to 10 feet. There is rarely a set striking N. 45°–50° W.

BAILEYVILLE.

The **Hall quarry** ("black granite") is in the town of Baileyville, at the north edge of Meddybemps Lake, 5 miles southwest of Baring, on the Washington County Railroad, about 7 miles southwest of Calais. Operator in 1905, F. H. Hall, Calais. The quarry is no longer operated.

The rock (specimens D, XXVI, 98, b, d) is a norite of brilliant luster, very dark gray shade without any yellowish tinge and of coarse texture and marked rift, with jet-black particles up to 0.5 inch in diameter in a network of translucent whitish feldspar. Under the microscope it consists, in descending order of abundance, of elongated transparent crystals of feldspar (with both soda and lime, andesine-labradorite) interlaced, but parallel in the flow and rift direction, with the intervening spaces filled with hypersthene (partly altered to brown hornblende), magnetite, and black mica (biotite), together with accessory calcite and a white mica derived from the partial alteration of a few of the feldspars. The hypersthene and hornblende constitute the conspicuous black particles seen with the unaided eye. In the lighter bands of the rock the feldspar largely crowds out the hypersthene. The content of magnetite is so great that large blocks of the rock deflect the magnetic needle. Mr. Hall stated that the stone endures the fire and water test very well; that its compressive strength, as determined by the Watertown Arsenal testing machine, is 22,500 pounds to the square inch, and that an assay by Carmichael, of Boston,

shows it to contain a small percentage of gold. The papers that give formal evidence of these results, having, unfortunately, been misplaced, can not be cited here. The stone takes a high polish, and the hammered and cut surface is almost white. It is very tough but splits with facility along the rift.

The quarry, opened in 1902, consists of two adjacent openings on the northeast side of a northwest-southeast ridge over one-fourth mile long and about 50 feet high. These openings measure 60 by 25 feet and 35 feet in depth and 50 by 20 feet and 20 feet in depth, respectively.

Rock structure: The upper 8 feet of the working face is traversed by light-gray more feldspathic bands 0.25 to 2 inches thick, constituting a flow structure parallel to the sheets, which are from 1 to 6 feet thick and dip about 15° SW. Vertical joints strike northeast-southwest, cross the ridge at intervals of 6 inches to 7 feet, and form a heading in the smaller northwesterly opening. The rift is parallel to the sheets. The structure along this ridge is unusually favorable for quarrying.

Transportation, by cart 5 miles to Baring, on the Washington County Railroad.

Specimen monuments: A monument erected by Stephen A. Lovejoy at Melrose Cemetery, Melrose, Mass.

The **Tarbox quarry** ("black granite") is in the town of Baileyville, about 900 feet northeast of the Hall quarry, described above, at the north edge of Meddybemps Lake, 5 miles southwest of Baring, on the Washington County Railroad, and about 7 miles southwest of Calais. Operator, Redbeach Granite Co., Redbeach.

This rock is a norite identical with that of the Hall quarry. It appears to belong to an outcrop northeast of and parallel to the ridge referred to.

CALAIS.

Gardner's prospect ("black granite") is in the town of Calais, on St. Croix River, 6 miles south of Calais, north of road to Redbeach. Owner, Lorenzo Gardner, Calais.

This rock (specimen D, XXVI, 100, a) is a quartz diorite of very dark gray (not bluish) shade and fine, even-grained texture, consisting, in descending order of abundance, of a whitish soda-lime feldspar (andesine) considerably altered to a white mica, hornblende partly altered to chlorite, quartz, black mica (biotite), and magnetite, together with accessory titanite, pyrite, and apatite and secondary calcite. It takes a high polish, and the hammered and cut surfaces are very light. The stone is suitable for monumental work. Dr. George Otis Smith, who visited the Gardner prospects in 1903, states that "pink granite occurs intrusive in the dioritic rock in such a manner that both kinds of stone could be quarried from the same opening." One part of the dioritic rock he found in thin section to be in reality a diabase.

The **Mingo-Bailey quarry** ("black granite") is in the town of Calais, about 6 miles south of Calais, on the southwest side of the road to Redbeach, on the north side of an east-west ridge, near top. Operators, Mingo, Bailey & Co., Redbeach.

The rock (specimen D, XXVI, 103, a) a norite, is almost black with a slight greenish tinge and of fine to medium even-grained ophitic texture. It consists, in descending order of abundance, of a whitish soda-lime feldspar (andesine) considerably altered to a white mica, hypersthene (some of it partly or entirely altered to fibrous actinolite), magnetite, and black mica (biotite), with accessory pyrite. The stone takes a fine polish and affords a very light hammered or cut surface.

The quarry measured 50 by 15 feet and up to 20 feet in depth in 1905 The sheets are about 10 feet thick. Vertical joints, strike about east to west, recur at intervals of 1 to 3 feet.

The quarry is worked only occasionally, and the stones are carted to the company's cutting shed, near Redbeach, on St. Croix River.

The **Beaver Lake quarry** ("black granite") is in the town of Calais, near the north end of Beaver Lake, 4 miles west of Red Beach village. Operator, Maine Red Granite Co., Red Beach. Quarry idle.

The rock (specimen D, XXVI, 96, g) is a mica-quartz diorite of general dark-gray shade (black mottled with white and gray) and of coarse to medium porphyritic texture, with feldspars up to 0.5 inch in diameter. It consists, in descending order of abundance, of a grayish feldspar containing both soda and lime (andesine-labradorite), black hornblende, black mica (biotite), magnetite, and a little quartz, together with accessory pyrite, calcite, and apatite. The feldspar is partly altered to kaolin and a white mica, producing the milky-white parts of the feldspars seen in the polished specimen, and some of the hornblende is fibrous. The stone takes a high polish and when hammered or cut has a very light surface.

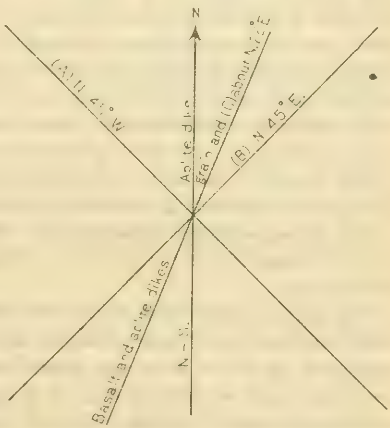


FIGURE 67.—Structure at the Beaver Lake diorite quarry, Calais, Maine.

The quarry, opened in 1885, measured in 1905 250 feet from north-northeast to south-southwest by 75 feet across and had a working face on the east 30 feet in height.

Rock structure: The sheets, 6 inches to 7 feet 6 inches thick, dip 15° W. and are lenticular. The upper 10 feet of the face consists of shattered surface rock and includes a bed 1 foot thick of sand, due to interstitial weathering. The courses of joints and dikes are shown in figure 67. (A) recurs at intervals of 2 to 10 feet, (B) at intervals of 10 feet, (C) still less frequently. There are also irregular joints, which break the rock up into irregular blocks.

A dike of pinkish aplite, 4 to 8 feet thick, runs the entire length of the quarry on the west. A 1-inch dike of white aplite dips 15° S. Similar dikes recur at frequent intervals. Some strike north and curve. A dike of olivine basalt occurs also on the west side or front of the quarry and is crossed by branches from the large dike of pinkish aplite. The rift is horizontal and the grain vertical, striking north-northeast. Thus, altogether, the structure and injections are complex and render the quarrying of large blocks difficult. Notwithstanding this, blocks of 9 by 9 feet by 20 inches have been obtained, and one 12 by 12 by 6 feet was in sight in 1905.

Transportation involves cartage of 4 miles to the company's cutting mill at Red Beach and a farther cartage of one-fourth mile to a wharf on St. Croix River.

The product is used entirely for monuments, of which the soldiers' monument at Calais is a specimen.

The **Shattuck Mountain quarry** is in the town of Calais, 3 miles west-southwest of Red Beach village, on Shattuck Mountain. Operator, Maine Red Granite Co., Red Beach. Quarry idle.

The granite (specimen D, XXVI, 104, b), "Shattuck Mountain," is a biotite granite of dark reddish to greenish-gray color and medium to coarse, even-grained texture, with feldspars up to 0.5 inch and sparsely disseminated biotite under 0.1 inch. It consists, in descending order of abundance, of a reddish potash feldspar (orthoclase), smoky quartz, greenish soda-lime feldspar (oligoclase), and black mica (biotite), together with accessory magnetite, apatite, and secondary chlorite. The oligoclase is here and there partly altered to a white mica. The smallness and sparseness of the micas are favorable to the durability of its polish.

The quarry, opened in 1890, consisted in 1905 of three openings on the south side of an east-west ridge. The principal opening measured 50 by 25 feet and from 10 to 20 feet in depth.

Rock structure: The sheets, 5 to 7 feet thick, are horizontal or dip south at a small angle. Joints, strike N. 25° E., dip 70° NNW., recur at intervals of 10 to 22 feet and form headings on the north and south sides of the quarry. Another set, strike N. 40° W., dip 65° W., forms a heading on the east side and recurs in middle of quarry. The heading of the first set on the north is about 6 feet thick and includes a bed of clayey sand 8 inches thick. It has three sets of subjoints, one striking N. 40° E., dipping 55° SE., spaced 2 to 12 inches; another striking N. 50° W., vertical, spaced 6 inches to 2 feet; and another striking N. 60° E., vertical, spaced 4 to 12 inches. The rock has no rift. The weathering of this granite has been referred to on page 70.

Transportation, by cart 3 miles to Red Beach, on St. Croix River.

The product is used for ornamental and monumental work. Specimens: Four fluted columns 22 by 3 feet, in the courthouse at Marquette, Mich.

The **Mingo-Bailey quarry** is in the town of Calais, 1½ miles north-northwest of Red Beach. Operators, Mingo, Bailey & Co., Red Beach. Quarry abandoned.

The granite (specimen D, XXVI, 102, b) is a biotite granite of dark-reddish color speckled with pale greenish and of medium, even-grained texture, with feldspars up to 0.4 inch and sparse biotite under 0.1 inch. It consists, in descending order of abundance, of a dark-pinkish potash feldspar (orthoclase), very smoky quartz, a pale yellowish to greenish soda-lime feldspar (oligoclase) considerably altered to a white mica, black mica (biotite), and accessory magnetite and zircon. The rock takes a high polish that exhibits marked contrasts between the two feldspars and the smoky quartz. The smallness and sparseness of the biotite scales favor the durability of the polish. The stone is of a lighter red than that of the Shattuck Mountain quarry, but is darker than that of the Maine Red Granite Co.'s "old quarry."

The quarry is 25 feet square by 8 feet deep.

Transportation, by cart 1½ miles to wharf at Red Beach.

The product is used entirely for monuments.

The **Maine Red Granite Co.'s quarry** is in the town of Calais, three-fourths mile west of Red Beach. Operator, Maine Red Granite Co., Red Beach. Quarry idle.

The granite (specimen D, XXVI, 97, a) is a biotite granite of general bright-pinkish-gray color and medium, even-grained texture, with feldspars up to 0.4 inch and sparse biotite scales under 0.1 inch. It consists, in descending order of abundance, of a pinkish potash feldspar (orthoclase), smoky quartz, cream-colored soda-lime feldspar (oligoclase), and black mica (biotite), together with accessory magnetite and zircon. The oligoclase is partly altered to kaolin and a white mica. The stone takes a high polish, the durability of which is favored by the sparseness and smallness of the mica scales. In weathering about the quarries the feldspars whiten from increasing kaoliniza-

tion. The contrasts are chiefly between the two feldspars and the smoky quartz. This type of "red granite" is the brightest of those occurring in Maine.

The quarry consists of two openings, one known as the "old quarry," opened in 1876, and a new one adjacent to it. The new one was in 1905 about 150 feet square by 20 to 50 feet deep.

Rock structure: The sheets, 6 inches to 5 feet thick, dip 10°–30° SE. Joints, strike N. 80° W., dip steep north, recur at intervals of 1 to 5 feet. Others, strike N. 40° E., dip 80° SE., recur at intervals of 6 inches to 5 feet. The faces of this set are coated with calcite and epidote. There is no rift whatever. It is evident from the frequent recurrence of both sets of joints and the small range in thickness of the sheets that the conditions are not favorable for quarrying large blocks. John E. Wolff[4] refers to the structure of "Redbeach granite."

Transportation, by cart, three-fourths mile to wharf on St. Croix River. The company's cutting and polishing works are one-fourth mile west of Red Beach.

The product is used entirely for monumental and ornamental work.

The **Red Beach Granite Co.'s quarry** is in the town of Calais, on Cooks Mountain, 8 miles southeast of Calais, about 1,000 feet southwest of road to Red Beach. Operator, Red Beach Granite Co., Red Beach.

The granite is a biotite granite of general bright pinkish-gray color and medium even-grained texture like that of the Maine Red Granite Co.'s quarry near Red Beach, described on page 266, and of the Bodwell Granite Co.'s abandoned quarry on Cooks Mountain.

The quarry, opened in 1895, is 50 by 25 feet and from 5 to 20 feet deep. The sheets, up to 5 feet thick, dip north at a low angle. Vertical joints strike N. 80°–90° E., forming numerous headings. There is no rift.

Transportation, by cart over half a mile to wharf on St. Croix River at Red Beach.

The product is used for buildings and monuments. Specimens: Red granite in two corner wings of the American Museum of Natural History, in New York; pedestal to General Grant's monument at Galena, Ill.

JONESBORO.

The **Fish quarry** is in the town of Jonesboro, 1 mile northwest of Jonesboro village. Owner, N. W. Fish, Jonesboro.

The granite (specimen D, XXVI, 87, b) is a biotite granite of lavender medium-gray color and medium, even-grained texture, with feldspars generally up to 0.4 inch (exceptionally 0.5 inch) and sparsely disseminated biotite up to 0.1 inch. It consists, in descending order of abundance, of a pale lavender-colored potash feldspar (orthoclase), smoky quartz, milk-white soda-lime feldspar (oligoclase), and a little black mica (biotite), together with accessory magnetite and secondary epidote, zoisite, and calcite. The feldspars are considerably altered to white micas, and the biotite is also largely altered to chlorite. This stone resembles that of the Goss and Ryan-Parker quarries of Crotch Island (p. 224) in the lavender tint of its orthoclase, but its texture is finer. Their resemblance may be found to be still greater in lower and fresher sheets.

The quarry, a small opening about 300 feet northwest of Mr. Fish's house, has been worked only occasionally. The sheets are up to 5 feet thick and lie horizontal.

The **Bodwell-Jonesboro quarry** is in the town of Jonesboro, 2 miles east of Jonesboro village. Operator, Bodwell Granite Co., Rockland.

The granite (specimen D, XXVI, 86, h), "Jonesboro red," is a biotite granite of general medium pinkish-gray color and of coarse, inclining to medium, even-

[4] Tenth Census, vol. 10, p. 116, 1888.

grained texture, with biotite sparsely disseminated and up to 0.05 inch in diameter. It consists, in descending order of abundance, of pinkish potash feldspar (orthoclase), smoky quartz, cream-colored soda-lime feldspar (oligoclase), and a little black mica (biotite), together with accessory magnetite and secondary white mica, kaolin, and chlorite. The orthoclase is intergrown with plagioclase, and the oligoclase is here and there largely altered to a white mica and kaolin and the biotite to chlorite. The contrasts are chiefly between the two feldspars and the smoky quartz. The stone takes a fine polish, the durability of which is favored by the smallness of the biotite scales.

The quarry, opened about 1875, measures about 700 feet N. 80° E.–S. 80° W. by 200 feet from north to south, and has a depth of 10 to 33 feet. Its area is irregular, as shown in figure 68. Its drainage requires occasional pumping.

Rock structure: This quarry shows a greater variety of dike courses than any other of the Maine quarries. The sheets, 6 inches to 5 feet thick, are horizontal, with slight undulations. The joint and dike courses are shown in figure 68. (A) recurs on the north and south sides of the quarry and in the middle, and forms a heading on the south; (B) forms a heading on the northwest side;

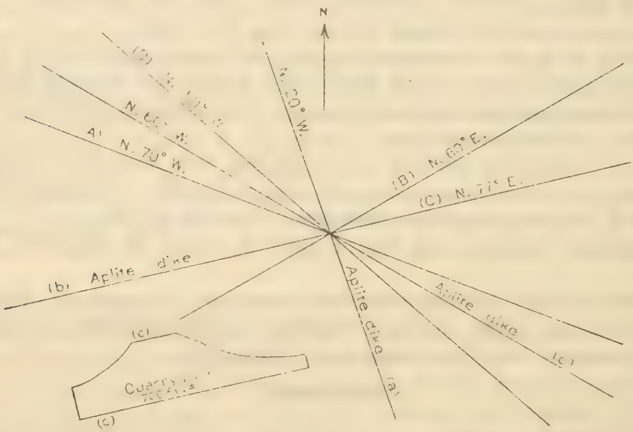


FIGURE 68.—General plan and structure at the Bodwell quarry, Jonesboro, Maine.

(C) appears on the south wall, intersecting the heading; (D) dips steeply south, and also intersects the south wall. The rift is vertical, with strike N. 70° W. There are two dikes of reddish aplite (*a*), one 6 feet thick, another 4 feet thick; a third (*b*), also reddish, is 3 to 6 feet thick; a grayish aplite dike (*c*), 1 to 1½ inches thick, can be traced from 200 to 300 feet, cutting all the other dikes. Thin sections of (*a*) are described on page 44. Knots occur up to 12 by 8 inches, but rarely. There are geodes and short veins, containing quartz, epidote, and calcite. (See p. 62.) The sheet surfaces are in places coated with epidote from the alteration of feldspar. John E. Wolff[5] has referred to the "Jonesboro red granite" and some of its peculiarities.

Transportation, by cart 1 mile to wharf on Englishmans Bay. The stone is shipped to Vinalhaven for finishing.

The quarry is not in operation for want of demand for granite of this color, but it is in good operating condition.

The product has been used for buildings. Specimens: Customhouse and post office, Buffalo, N. Y.; Methodist Book Concern Building; Havemeyer residence,

[5] Tenth Census, vol. 10, p. 116, 1888.

Fifth Avenue and Sixty-sixth Street, New York; customhouse and post office, Fall River, Mass.; Western Savings Bank Building, Philadelphia; and (since 1905) National Bank of Commerce, Kansas City, with two 2-story fronts with carved and polished surfaces; Dimock family mausoleum (Egyptian style), New London, Conn.

The **Booth Bros. Jonesboro quarry,** in the town of Jonesboro, is 1¼ miles east of Jonesboro village. Operator, Booth Bros. & Hurricane Isle Granite Co., 208 Broadway, New York.

The granite (specimen D, XXVI, 85, b), "Jonesboro red," is a biotite granite of general medium pinkish-gray color and coarse, inclining to a medium, even-grained texture, with sparsely disseminated biotite up to 0.05 inch in diameter. It consists, in descending order of abundance, of a pinkish potash feldspar (orthoclase), a little less pink than that of specimen 86, h, from the Bodwell quarry, smoky quartz, cream-colored soda-lime feldspar (oligoclase), and black mica (biotite), together with accessory magnetite and secondary white micas, zoicite, and chlorite. The orthoclase is here and there intergrown with a plagioclase. The oligoclase is largely altered to a white mica and kaolin, and the biotite to chlorite. The contrasts are between the two feldspars and the smoky quartz. The stone takes a high polish, the durability of which is favored by the smallness of the biotite plates. Its general color is not quite so pinkish as that of the Bodwell quarry.

The following chemical analysis of this granite was made by Ricketts & Banks, of New York (No. 16072), and is given here merely for the purpose of reference:

Analysis of granite from Jonesboro quarry.

Silica (SiO_2)	72.97
Alumina (Al_2O_3)	14.63
Ferrous oxide (FeO)	1.73
Lime (CaO)	1.48
Magnesia (MgO)	.27
Manganese oxide (MnO)	.10
Soda (Na_2O)	3.28
Potash (K_2O)	5.18
Sulphur (S)	.03
Carbon dioxide (CO_2)	None.
Loss and undetermined	.33
	100.00

The quarry is of triangular area, about 10 by 75 by 75 feet and 30 feet deep.

Rock structure: The sheets, 5 to 10 feet thick and lenticular, lie horizontal or dip 5° NW. or 5° SE. A vertical joint, strike N. 60° W., forms the wall on the southwest. A set striking N. 35°–50° E. forms headings on the northwest and southeast and recurs at intervals of 5, 10, 20, and 70 feet. Its faces are coated with hematite. The rift is vertical, with strike N. 60° W. The grain is horizontal. Knots are small and infrequent. Sap up to 3 inches thick is confined to headings. The structural conditions are unfavorable for quarrying large blocks.

Transportation, along a track one-third mile to wharf on Englishmans Bay.

The quarry is not in operation.

The product has been used for building.

JONESPORT.

The **Minerva Cove quarry** is in the town of Jonesport on the north side of Head Harbor Island, about 3½ miles southeast of Jonesport. Quarry no longer operated.

The granite (specimens D, XXVI. 88, a. and 88, b) is a biotite granite which in the lower sheets is of general dark reddish-gray color, with both a pinkish and a greenish feldspar, but in the upper sheets has a white instead of a greenish feldspar. It is of coarse, even-grained texture, the feldspars up to an inch in length and the biotite up to 0.2 inch. It consists, in descending order of abundance, of pinkish potash feldspar (orthoclase with a little microcline), smoky quartz, dull greenish or milk-white soda-lime feldspar (oligoclase) and black mica (biotite) in conspicuous flakes, together with accessory magnetite, pyrite, titanite, and apatite. The orthoclase, generally in twins, is intergrown with plagioclase. The oligoclase is largely altered to white mica and kaolin, particularly in the upper sheets, where it has passed from green to white. The quartz is cloudy from the presence of multitudes of irregular bubbles, the largest of which measure 0.01 millimeter, or about 0.0004 inch in length. It is also traversed by irregular fissures containing sericite. Some of the pinkish orthoclase is rimmed with white or greenish oligoclase or completely envelops a greenish oligoclase crystal. The contrasts are feeble in the granite of the lower sheets, owing to the darkness of the oligoclase and quartz, but are marked in that of the upper sheets, the four minerals all differing in shade.

The quarry consists of five openings—(1) 100 by 25 and 14 feet deep; (2) 50 by 25 and 40 feet deep; (3) 300 by 70 and 35 feet deep; (4) triangular, 100 by 150 by 75 feet deep, with working face 35 feet high; (5) 50 by 25 and 20 feet deep.

Rock structure: The sheets at the upper opening, 2 to 22 feet thick but usually 5 to 15 feet, dip 10° NE. Vertical joints striking N. 10° E. or north form a heading on the east and recur at intervals of 5 to 10 feet. Another set strikes east and dips 60° S., and one which may belong to it strikes N. 80° W. and dips 90°. The rift is horizontal; the grain vertical, striking north. Dikes of aplite up to an inch thick have N. 60° E. courses.

Transportation, by cart 700 feet and 50 feet down grade from upper opening to wharf. From the opening at the wharf stones are loaded by derricks directly on schooners.

The product was used for buildings. Specimens: Colorado Building, at Fourteeth and G Streets, Washington; State armory, Providence, R. I.; power house of the Metropolitan Street Railway (Interurban), Ninety-fifth to Ninety-sixth Streets and First Avenue to Hudson River, New York.

The **Hardwood Island quarry** is in the town of Jonesport, on Hardwood Island, which lies 3½ miles southwest of Jonesport village. Operator, Rockport Granite Co., Rockport, Mass.

The granite (specimen D, XXVI, 90, a), "Moose-a-bec red," is a biotite granite of general dark reddish-gray color, with a white and a pinkish feldspar, and of coarse, even-grained texture, like that of specimen 88, a, from Head Harbor Island, described above, but with an occasional isolated feldspar.

The Rosiwal method was applied to a specimen of this granite with a polished face 5 by 3 inches. The size of mesh was 0.9 inch; total length of lines, 40.20 inches. Owing to the irregular massing of the feldspar in the specimen a second test was made with the short set of lines shifted one-fourth inch, and the long set adjusted accordingly. The results of both tests were averaged for the final estimate.

Sizes and percentages of minerals in granite from Hardwood Island, as determined by the Rosiwal method.

Mineral.	First test.	Second test.	Averages.	
	Inches.	*Inches.*	*Inches.*	*Per cent.*
Reddish orthoclase	10.12	12.46	11.29	28.85
Milk-white oligoclase	8.00	8.24	8.12	22.45
Biotite	1.72	1.54	1.63	4.05
Smoky quartz	20.36	17.96	19.16	44.65
	40.20	40.20	40.20	100.00

Percentage of both feldspars, 51.30.

This granite takes a fine polish, in which the contrasts between the pinkish and white feldspars and the black mica stand out on the background of smoky quartz. Some of the pinkish feldspars are bordered by the white. The large size (usually 0.1 inch) of the biotite scales is against the durability of the polish under long-continued outdoor exposure.

The quarry measured in 1905 150 by 60 feet and 15 feet in depth, but its bottom was between tide levels. There is no stripping.

Rock structure: The sheets, 2 to 10 feet thick, are horizontal but in places curve seaward. Joints, strike N. 75° W., dip 65° S., recur only at rare intervals. Others, strike N. 45° W. and vertical, recur at intervals of 18 feet and over. The rift is vertical, with strike N. 10° E. Dikes of aplite up to 6 inches thick strike N. 25° W.

Transportation, by lifting the blocks onto the wharf, which is 125 feet from the quarry.

The product is used for buildings. Specimens: Wainscoting and stairway in main entrance to Suffolk County Courthouse, Boston; the American Baptist Publication Society Building, Philadelphia; 25 columns in the Catholic Cathedral in Newark, N. J.; Germania Life Insurance Building, New York; Miami Hotel, Dayton, Ohio; Cuyahoga Hotel, Cleveland, Ohio; Old State National Bank, Evansville, Ind.; city baths, Kansas City, Mo.

MARSHFIELD.

The **Marshfield quarry** is in the town of Marshfield, 3 miles north of Machias. Operators, Butler & Berry, Machias.

The granite (specimen D, XXVI, 84, b) is a biotite granite of medium pinkish-gray color and of medium to fine, even-grained texture, with feldspars from 0.1 to 0.4 inch and sparsely disseminated biotite under 0.1 inch in diameter. It consists, in descending order of abundance, of pinkish potash feldspar (orthoclase), smoky squartz, cream-colored soda-lime feldspar (oligoclase), and a little black mica (biotite), together with accessory magnetite, titanite, and zircon and secondary kaolin, white micas, and chlorite. The orthoclase is intergrown with plagioclase, the oligoclase is much altered to kaolin and a white mica, and the biotite is partly chloritized. Molybdenite occurs here and there. The granite is slightly less pinkish than that from the quarry of Booth Bros. at Jonesboro (specimen 85, b). The contrasts are also reduced by the greater fineness of the particles. It takes a fine polish, the durability of which is favored by the sparseness and smallness of the biotite scales.

The quarry, opened about 1894, measured in 1905 200 by 150 feet and 2 to 10 feet in depth.

Rock structure: The sheets, 1 to 8 feet thick, dip irregularly up to 10° SW. and NW. Vertical joints, strike N. 55° E., form headings on the north and south sides. Another set, strike N. 60° W., dip 70° SW. to 90°, forms headings near the east side and recurs at intervals of 10 to 50 feet. A third and diagonal set, strike No. 85° E., dip 55° N., recurs irregularly. There is some "toeing in" of sheets, probably owing to faulting along the set of joints striking N. 55° E. The faces of the second set are coated with epidote, and those of the third with pyrite. The rift is horizontal. There are geodes (up to 6 inches thick) of orthoclase and oligoclase, smoky quartz, amethyst, and pyrite filled with calcite, epidote, and chlorite. Sap is 2 inches thick in the upper sheets only.

Transportation, by cart 3 miles to railroad or wharf at Machias.

The product is used for monuments and buildings. Specimens: Basement front and steps of E. S. Draper residence, Beacon Street, Boston; also monuments for Boston and for local demand.

MILLBRIDGE.

The **Millbridge quarry** is in the town of Millbridge, near Millbridge village, in the southwestern part of Washington County. Operators, Swanton & Wallace, Millbridge. Quarry abandoned.

The granite (specimen D, XXVII, 143, a) is a biotite granite of medium buff color and of medium, even-grained texture, with feldspars up to 0.3 inch (exceptionally 0.5 inch) and biotite scales under 0.1 inch. It consists, in descending order of abundance, of a buff-colored potash feldspar (orthoclase), smoky quartz, very slightly greenish-white soda-lime feldspar (oligoclase), and black mica (biotite), together with accessory magnetite and apatite. The quartz has numerous very irregular bubbles up to 0.028 millimeter in length. The orthoclase is intergrown with a plagioclase. Granulation ("crush borders") occurs along the contacts of the feldspars with one another. The stone takes a high polish, the durability of which is favored by the smallness of the biotite scales.

Some tests of a Millbridge granite, quarried at White Rock Mountain by S. L. Treat & Co., were made in 1895 by the United States Ordnance Department at the Watertown Arsenal.[6] These give it a shearing strength of 2,820 pounds, a transverse strength of 2,069 pounds, and a compressive strength of 19,917 pounds to the square inch.

The Millbridge quarry was not visited by the writer, and the firm failed to reply to questions as to dimensions of quarry and product.

YORK COUNTY.

ALFRED.

The **Bennett quarry** is in the town of Alfred, 1 mile southwest of Alfred village, south of the Portland & Rochester Railroad, at the north foot of a 480-foot hill. Operators in 1905, Bennett Bros, Alfred. Quarry no longer operated.

The rock (specimen D, XXVII, 153, a) is a quartz diorite of slightly greenish dark-gray color, with conspicuous black mica, and of medium, even-grained texture, with feldspars up to 0.25 inch and biotite scales under 0.2 inch. It consists, in descending order of abundance, of a grayish soda-lime feldspar

[6] Tests of metals, etc., for 1895, pp. 319, 325, 344, 409, 1896.

(oligoclase), black mica (biotite), quartz (smoky or milky), dark hornblende and magnetite, with accessory titanite, zircon, apatite, and secondary epidote and a white mica. The oligoclase is often in good-sized twins and is intergrown with orthoclase and quartz and generally cloudy and altered by a white mica. The only contrast in this stone is that between the gray of the feldspar and quartz and the black of the mica. After one or two years' exposure the feldspar loses its slightly bluish tinge and assumes a greenish one, which is attributed to the oxidation of its ferrous oxide. (See further p. 76.)

The quarry, opened prior to 1875, measured, in 1905, 60 by 150 feet and up to 30 feet in depth.

Rock structure: The sheets, up to 12 feet thick, and inclined, are crossed by vertical joints, strike N. 70° E., recurring at intervals of 10 feet and forming a heading 8 feet wide in center of quarry. Another set, also vertical, strike N. 20°–25° W., recurs at intervals of 20 feet. The rift is horizontal, and the grain vertical, with strike N. 70° E. The sap is 2 inches thick along the sheets. A vertical bed of sand, 6 inches thick, lies in the central heading.

Transportation, by cart 1 mile to Alfred railroad station.

The product was used for curbing and buildings. Specimen: Parsons Memorial Library, Alfred village.

BERWICK.

The **Spence & Coombs quarry** ("black granite") is in the town of Berwick, 1½ miles southeast of North Berwick village and station. Operators, Perry Bros., Concord, N. H.

This rock (specimen D, XXVII, 139, a) is a gabbro of very dark olive-brownish color and medium ophitic texture, consisting, in descending order of abundance, of longitudinal crystals of grayish olive-brownish lime-soda feldspar (labradorite) between which are particles of diallage, black mica (biotite), magnetite, and a little pyrite, together with secondary hornblende, analcite, zoisite, and calcite. The freshly quarried stone becomes somewhat brownish on exposure. It takes a high polish, and the cut or hammered surface is light gray.

The quarry consists of two openings, in 1905 about 25 feet square by 5 to 10 feet deep.

Rock structure: The sheets, 6 to 8 feet thick, lie nearly horizontal and are crossed by vertical joints striking N. 25°–30° W. and by another set striking N. 45° E. and dipping 65° SE. and recurring at intervals of 6 to 20 feet.

The quarry is worked only occasionally, and the stone is used entirely for monuments.

The **Miniutti quarry** ("black granite") is in North Berwick, in the township of Berwick. Operators, Miniutti Bros. & Co., Concord, N. H. Idle in 1922.

The granite (specimen D, XXXVIII, 27, a) "North Berwick black granite," is a gabbro of very dark olive-greenish color and ophitic medium texture, with feldspars up to 0.4 inch. It consists, in descending order of abundance, of olive-brownish lime-soda feldspar (labradorite), diallage, hornblende, biotite, magnetite, quartz, and very little pyrite. Secondary minerals are the hornblende, zoisite, chlorite, calcite. It takes a high polish, and the polished face has an extremely dark olive color and shows in oblique light many grains of magnetite. The cut or hammered face is light gray.

The quarry was opened about 1912.

The stone is used for inscribed monuments.

BIDDEFORD.

The **Ricker quarry** is in Biddeford city, at 19 Granite Street. Operator, George H. Yates, Biddeford.

The granite (specimen D, XXVII, 129, a) is a biotite granite of general light-gray shade with conspicuous smoky quartz and slightly bluish-white feldspar, and of coarse, even-grained texture, with feldspars up to 0.75 inch and biotite under 0.2 inch. It consists, in descending order of abundance, of a slightly bluish milk-white potash feldspar (microcline and orthoclase), dark smoky quartz, milk-white soda-lime feldspar (oligoclase), and black mica (biotite), together with accessory magnetite, zircon, and apatite and secondary white mica and kaolin, derived from the alteration of the oligoclase. The contrasts in this granite are unusually brilliant. They are between the white of the feldspars, the gray of the very vitreous quartz, and the black of the mica. The stone takes a fine polish, but the largeness of the biotite scales does not favor its durability under exposure to the weather.

The quarry, opened in 1865, was in 1905 100 by 50 feet and from 5 to 25 feet deep.

Rock structure: The sheets, up to 12 feet thick, are crossed by joints, strike N. 50° E., dip 55° NW., which recur at intervals of 2 to 20 feet, and by a set striking N. 45° W. and dipping 60° S. W., which recur at intervals of 2 to 10 feet and over.

Transportation, by cart 1 mile to railroad.

The product is used for monuments, etc.

The **Gowen Emmons quarry** is in Biddeford city, at 17 Granite Street. Operator, Frank Morin, Biddeford.

The granite (specimen D, XXVII, 128, a) is a biotite granite of general light-gray shade, with conspicuous smoky quartz and slightly bluish-white feldspar,

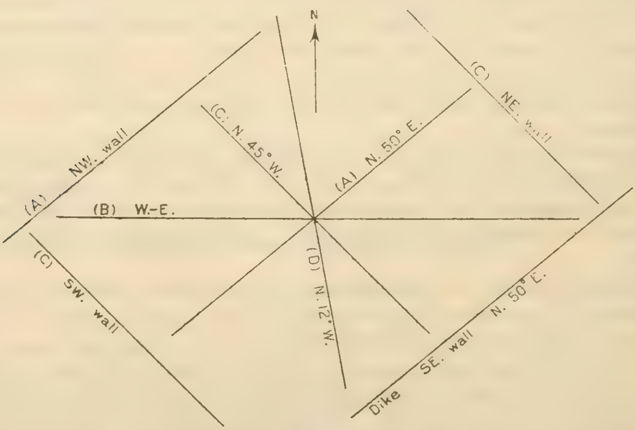


FIGURE 69.—Structure at the Gowen Emmons quarrp, Biddeford, Maine.

and of coarse, even-grained texture, with feldspars up to 0.75 inch and biotite under 0.2 inch. It is identical with that of the Ricker quarry (specimen 129, a), described above. In the sheets nearer the surface the feldspar is slightly grayish or greenish, diminishing the contrasts.

The quarry, opened about 1865, consisted in 1905 of two openings, an old one 200 feet from northeast to southwest, 100 feet across, and from 30 to 70 feet deep, and a new one 250 feet from northeast to southwest, 200 feet across, and 10 to 60 feet deep.

Rock structure: The sheets, 1 to 12 feet 6 inches thick, increasing in thickness downward, undulate horizontally. The joint courses are shown in figure 69. (A), dip 55° NW., recurs at intervals of 2 to 20 feet; (B), dip 70° S., occurs exceptionally; (C), dip 60° SW., forms the northeast and southeast walls and recurs at intervals of 2 to 10 feet or more; (D), dip 65° E., occurs exceptionally. The rift is vertical, N. 60° W.; the grain is horizontal. On the southeast wall there is a basic dike up to 1 foot thick and nearly parallel to joints (A). Black knots occur up to 6 inches across. Sap is 6 inches thick on both sides of upper sheets but diminishes below.

Transportation, by cart 1 mile to railroad.

The product is used for buildings and monuments. Specimens: Hospital, Dover, N. H.; Lincoln Monument, Springfield, Ill.

The **Wormwood quarry** is in the town of Biddeford, 1¼ miles southwest of Biddeford city, in West Biddeford. Operators, Ira T. Wormwood & Sons, Biddeford. Idle since 1916.

The granite (specimen D, XXVII, 130, a) is a biotite granite of general medium pinkish-buff color and of coarse, even-grained texture, with feldspars up to 0.75 inch and biotite up to 0.15 inch. It consists, in descending order of abundance, of a pinkish-buff potash feldspar (microcline and orthoclase), dark smoky quartz, cream-white soda-lime feldspar (oligoclase), black mica (biotite), and a very little muscovite, together with accessory magnetite and secondary epidote, chlorite, kaolin, and white micas. The oligoclase is considerably altered to kaolin, a white mica, and epidote, and the biotite to chlorite. The contrasts in this stone are chiefly between the pinkish-buff and white feldspars and the smoky quartz, to which the black mica adds another element. As some of the potash feldspars are more pink and others more buff, it has in all five colors and shades.

The quarry is 40 by 20 feet and 6 to 8 feet deep.

Rock structure: The sheets, 7 feet thick (increasing to 15 feet lower down the hill), are crossed by vertical or steep joints, strike N. 80°–85° W., which recur at intervals of 20 feet, and others strike N. 40° E., which recur at intervals of 35 feet with headings. Sap is 1 to 2 inches thick along the top sheet, but 4 inches along the headings. A bunch of knots up to 8 inches thick and of egg-shaped outline was noticed.

Transportation, by cart 1 mile to railroad siding.

The product is used for buildings. Specimen: Trimmings on St. Joseph's Church, Biddeford. (Material for the dry dock at Charlestown, Mass., was quarried at an old adjacent opening.)

The **Andrews quarries** are in the town of Biddeford, about 1½ miles southeast of Biddeford city and half a mile south of Saco River. Operator, George Willett Andrews, Biddeford. Quarry abandoned.

The granite (specimen D, XXVII, 133, a) is a biotite granite of general light-gray color, with conspicuous black mica, and of coarse, even-grained texture, with feldspars up to 0.75 inch and biotite up to 0.2 inch. It consists, in descending order of abundance, of a translucent bluish-white potash feldspar (microcline and orthoclase), light smoky quartz, milk-white soda-lime feldspar (oligoclase), and black mica (biotite), together with accessory magnetite, titanite, zircon, and apatite and secondary kaolin and a white mica derived from the alteration of the oligoclase. The feldpsars are considerably intergrown with quartz, some circular in cross section. The contrasts are between the feldspars, quartz, and mica. The feldspar is more bluish than that of the Ricker and Gowan Emmons quarries.

The quarries, opened in 1862 and again in 1895, consist of six small openings of various dimensions, only one of which—a "boulder quarry"—was worked in 1905.

Rock structure: The rift is horizontal, and the grain vertical, striking northwest-southeast, but the difference between them is not marked. The jointing permits the quarrying of blocks up to 25 feet square. Sap is 2 inches thick. Knots in some of the openings are up to 3 and even 10 feet long.

Transportation, by cart half a mile to Saco River, or 2 miles to railroad at Biddeford.

The product is used for buildings, monuments, etc. Specimens: Tribune Building, New York; General Dix monument, Fort Monroe, Va.; foundation and trimmings of Watson & Miller Building, Portland, Maine. This quarry has furnished granite for the Delaware and Saco River breakwaters and curbing for Dover and Rochester, N. H.

HOLLIS.

The **Bear Hill quarry** is in the town of Hollis, on Bear Hill, 1 mile west-southwest of Bradbury station (Hollis Center), on the Portland & Rochester Railroad. Operator in 1905, E. M. Bradbury, Hollis Center. Quarry disused.

The granite (specimen D, XXVII, 136, a) is a biotite-muscovite granite of medium to light gray shade with a slight greenish tinge, evenly spangled with black and white mica, and of medium, inclining to fine, even-grained texture, with feldspar up to 0.3 inch and mica up to 0.1 inch. It consists, in descending order of abundance, of a grayish potash feldspar (orthoclase and microcline), slightly smoky quartz, grayish soda-lime feldspar (oligoclase), black and white mica (biotite and muscovite), with accessory apatite and a secondary white mica, As the quartz is about of the same shade as the feldspar, the only contrast is between the gray ground and the micas.

The quarry, reopened in 1901 (begun in 1855), consists of an older opening of irregular shape, from which about 700 cubic yards have been quarried and an acre stripped, and a later opening 50 feet square and 5 to 10 feet deep.

Rock structure: The sheets are lenticular, up to 6 feet thick, and horizontal. Vertical joints, strike N. 55° W., form a heading on the southwest; other joints, strike N. 30°–35° E., recur at intervals of 30 feet or more. The rift (horizontal) is marked, and the grain is vertical, striking east. Pegmatite dikes, up to 6 feet thick, strike N. 10°–20° W., recur at intervals of 30 feet or more and in places branch. They consist of quartz, feldspar, biotite, and muscovite. A basic dike, 1 to 12 inches thick, with a course N. 30° E., traverses the entire quarry, crossing the pegmatite dikes. The sap is marked on the upper sheet and also along the joints and up to 6 inches thick.

Transportation, by cart one-fourth mile to railroad.

The quarry produced stone for the foundation of a pulp mill (Bar Mills) and for a dam on Saco River.

KENNEBUNKPORT.

The **Day quarry** is in the town of Kennebunkport, 3 miles southwest of Biddeford. Operators, A. H. Day & Co., Biddeford. Idle since 1913.

The granite (specimen D. XXVII, 131, a) is a biotite-muscovite granite of medium-gray shade, with conspicuous black mica, and of coarse, even-grained texture, with feldspars up to an inch across and biotite scales up to 0.2 inch. It consists, in descending order of abundance, of a gray, in places very slightly buff-pinkish, potash feldspar (microcline and orthoclase), very smoky quartz, milk-white soda-lime feldspar (oligoclase), black mica (biotite), with a little white mica (muscovite). The contrasts in this granite are marked.

The quarry, opened about 1899, was in 1905 50 feet square and 25 to 30 feet deep.

Rock structure: The sheets, 4 to 14 feet thick, dip 10° E. Joints, strike north, dip 60° W., form a heading on the west and recur at intervals of 30 feet or more. One striking northwest dips 80° SW.; another strikes N. 80° E., and still another strikes northeast and dips 40° SE. This is a "boulder quarry." The rift is horizontal, and the grain N. 70°–75° W., but they are not marked. Sap, 2 to 3 inches thick, occurs along the joints.

Transportation by cart 1 mile to railroad siding.

The product is used for bridge work, and some of it was used in the dry dock at Kittery, Me., and some for bridges on the Boston & Maine Railroad.

The **Ross quarry** is in the town of Kennebunkport, 3½ miles southwest of Biddeford. Operators in 1905, Ellis & Buswell, Woburn, Mass. Quarry no longer operated.

The granite (specimen D, XXVII, 132, a) is a biotite granite of general light-gray shade, with translucent milky-white feldspars, dark, smoky quartz, and black mica, and of coarse, even-grained texture, with feldspars up to 1 inch across and biotite scales under 0.2 inch. It is similar to that of the Ricker and Gowan Emmons quarries, described on page 274.

The quarry, opened in 1887, was in 1905 about 200 feet square and 35 feet deep.

Rock structure: This is a typical "boulder quarry," with irregular joints, as shown in figure 70. The sheets, 14 to 22 feet thick, are horizontal or dip 30° E., but irregularly. A basic dike, 10 inches thick, forms the northwest side of the quarry and is said to continue for one-fourth mile N. 50° E. The joints run in four directions, none of them at right angles to another and none of them vertical. Sap is 3 to 6 inches thick along the sheets. Knots up to 6 inches thick are not abundant.

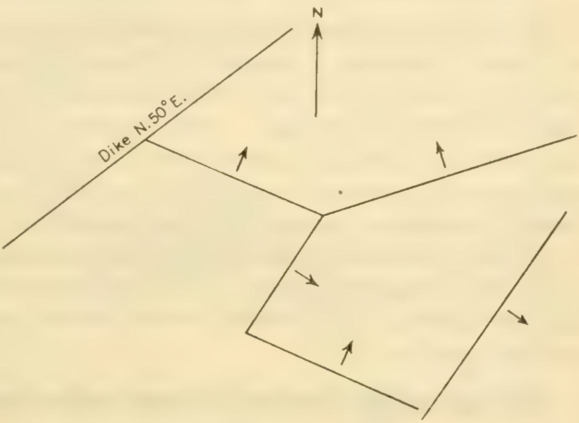


FIGURE 70.—Approximate structure at Ross (Ellis & Buswell) "boulder quarry," Kennebunkport, Maine. The small arrows show the direction of dip of joints.

Transportation, by cart one-third mile to siding on Boston & Maine Railroad.

The product was used mostly for bridge work. Specimen structures: Gateway at Hope Cemetery, Kennebunk, Maine (except the balls on the posts); Renwick tomb, cemetery near Kittery, Maine; railroad bridge, Haverhill, Mass.

WELLS.

The **Lord quarry** is in the town of Wells, about 1 mile east-northeast of Wells Depot on the Boston & Maine Railroad (eastern division), near a school house at a road fork. Operator, Granville W. Lord, Wells Depot. Idle since 1915.

The granite (specimen D, XXVII, 138, a) is a biotite granite of light pinkish-gray color, with sparse conspicuous biotite, and of medium to coarse, even-grained texture, with feldspars up to 0.5 inch and biotite scales up to 0.2 inch.

It consists, in descending order of abundance, of a delicate pink potash feldspar (microcline and orthoclase), with slightly smoky quartz, cream-white soda-lime feldspar (oligoclase), and black mica (biotite), together with accessory magnetite and zircon and secondary white mica and chlorite. The potash feldspars are both intergrown with plagioclase. The oligoclase is intergrown with quartz in particles circular in cross section and is partly altered to a white mica and the biotite to chlorite

The stone takes a good polish, but the large size of the biotite scales is not favorable to the durability of the polish in outdoor exposure. The contrasts are chiefly between the grayish-pinkish ground and the black mica.

The openings are small. The sheets, 1 to 3 feet thick, are horizontal. Vertical joints strike N. 10° E. and N. 70° W. The rift is horizontal. Sap is 2 inches thick along the sheets.

MASSACHUSETTS.

DISTRIBUTION OF GRANITE-QUARRYING CENTERS..

The chief commercial granites of Massachusetts are in the counties of Essex (Rockport, Peabody, Middlesex (Graniteville, Westford), Norfolk (Quincy), Bristol (Fall River, New Bedford), and Worcester (Milford, Uxbridge). The location of the quarrying centers and isolated quarries is shown in Plate XXIII. The areal extent and probable geologic age of the granites will be found on the recently published geologic map of the State.[7]

A brief reference to the geology will preface the quarry descriptions of each granite center. The counties will be taken up, as in the other States, in alphabetic order. Some counties have only one or two quarries.

THE QUARRIES, THEIR GRANITE AND FINISHED PRODUCT.

BERKSHIRE COUNTY.

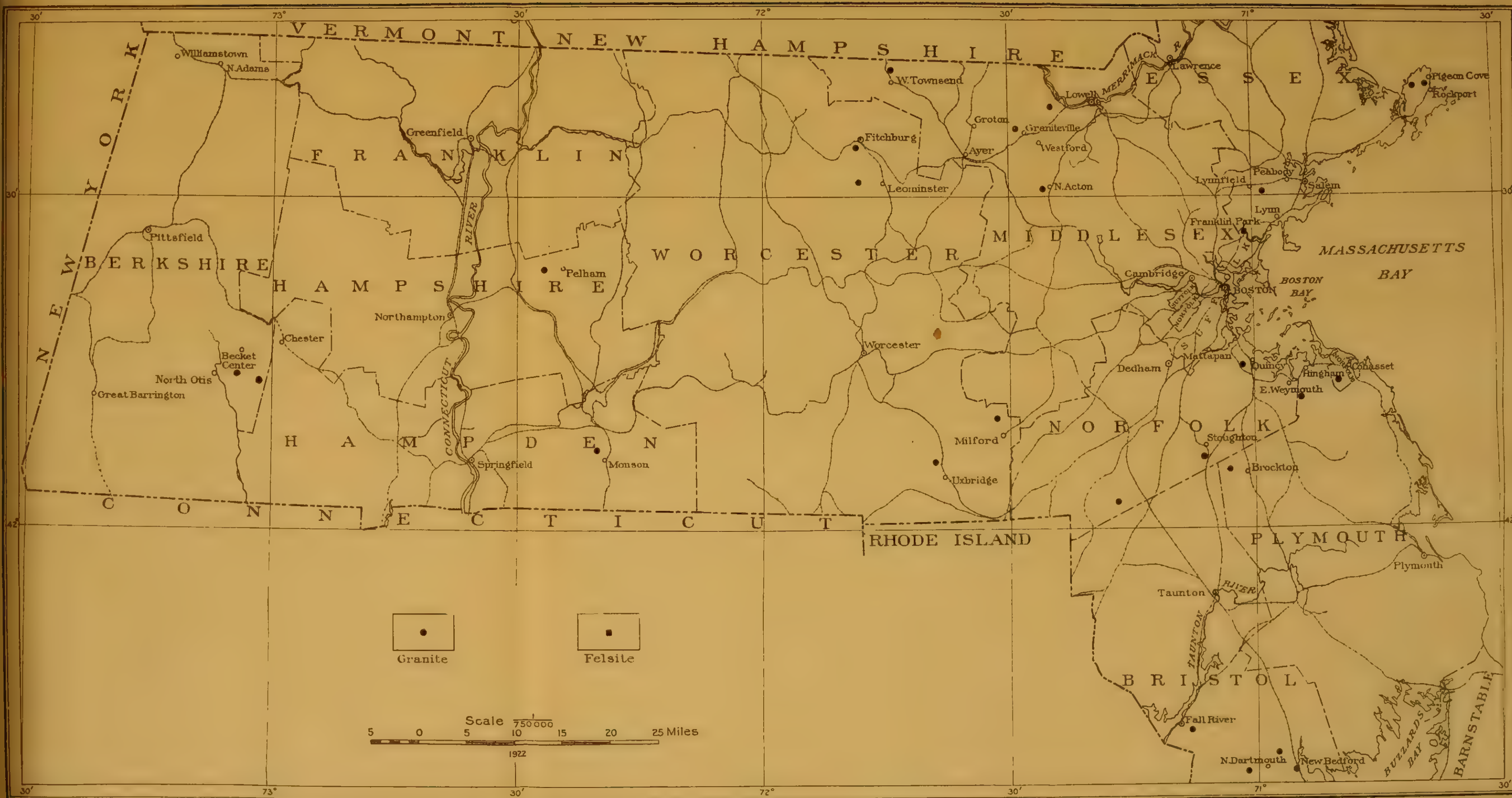
The quarries in Berkshire County are in the towns of Becket and Otis. These towns are on the southern continuation of the Green Mountain range in the east-central part of the county. The range attains thereabouts elevations of 1,750 and 1,845 feet, but is deeply cut by south-southeasterly valleys, through which flow branches of Westfield River, and by minor north-south and east-west tributary hollows.

GEOLOGIC RELATIONS.

The geology of the region has been described by Emerson.[8] There is a large area of Becket granite gneiss, in places, however, with very slight gneissic structure. This is regarded as of Archean age, although similar fine-grained gneisses in the same range in Vermont are probably Algonkian. At the quarry in Becket the granite is in contact with an overlying mass of black schistose quartz-mica diorite containing both potash and soda-lime feldspar, and along

[7] Emerson, B. K., Geology of Massachusetts and Rhode Island: U. S. Geol. Survey Bull. 597, pl. 10, 1917.

[8] Idem, pl. 10, pp. 153, 154, 1917.



MAP OF MASSACHUSETTS SHOWING LOCATION OF GRANITE QUARRIES.

the contact the granite has a banded flow structure. Emerson regards this rock (Lee quartz diorite) "as a contact zone of the Becket granite gneiss and to have originated by differentiation in place." The field observations indicate either the inclusion of a large mass of the diorite schist by the granite or else an intrusion of the granite in an overlying diorite schist. At the quarry in Otis, besides the Becket granite gneiss, plicated schist a few feet thick, of uncertain age, is exposed.

BECKET.

The **Hudson & Chester quarry** is in the town of Becket, 1 mile west of longitude 73° and latitude 42° 15′, 1,400 feet above sea level, 2¾ miles southwest of Chester, on the Boston & Albany Railroad. (See Becket and Chesterfield topographic maps, U. S. Geol. Survey.) Operator, Chester Granite Quarries Co., Chester.

The granite (specimens D, XXIX, 91 f, g, k), "Chester dark" and "Chester light," is a muscovite-biotite granite of medium inclining to dark bluish-gray to medium bluish-gray color and of fine texture, with feldspars up to 0.15 inch and mica in very fine particles. The texture of this granite is neither exactly gneissoid, porphyritic, nor even grained. In thin section the coarser particles of quartz and feldspar are seen to lie in a somewhat micaceous matrix of very fine texture, and there is not a little granulation about the feldspars. The average diameter of the particles of this matrix, estimated by the Rosiwal method, is less than 0.005 inch, which is finer than in the finest Westerly granite (p. 407), although the stone as a whole is coarser texture than that. Its constituents, in descending order of abundance, are light bluish-gray potash feldspar (microcline, rarely orthoclase); slightly bluish quartz, with sheets of cavities (up to 0.02 millimeter in diameter) in two rectangular directions with brightly polarizing rift and grain cracks parallel to them; light bluish-gray soda-lime feldspar (oligoclase-albite); white mica (muscovite); and black mica (biotite). The only difference between the dark and light varieties is in the percentage of the black mica. Accessory: Titanite, pyrite, ilmenite, allanite, fluorite, apatite, and zircon. Secondary: Muscovite, carbonate, and epidote (as rim about allanite). The amount of titanite is relatively large.

Kemp [9] has described this granite.

An estimate of the mineral percentages in this granite, by the application of the Rosiwal method to a camera lucida drawing of a thin section enlarged 37 diameters, with a mesh of 1.2 inch and a total linear length of 25.85 inches, yields the following results:

Estimated mineral percentages in granite from Becket, Mass.

Quartz	49.35
Potash feldspar (orthoclase 17.05, microcline 11.50)	28.55
Soda-lime feldspar (oligoclase-albite)	15.37
Mica (muscovite, 4.10, biotite, 2.47)	6.57
Titanite	.16
	100.00

[9] Kemp, J. F., On the granite quarried at Chester, Mass.: New York Acad. Sci. Trans., vol. 11, for 1891–92, pp. 129–130.

The following analysis, by Prof. L. M. Dennis, of Cornell University, is quoted by Kemp in the paper referred to:

Analysis of granite from Becket, Mass.

Silica (SiO_2)	69.465
Alumina (Al_2O_3)	17.50
Iron sesquioxide (Fe_2O_3)	2.30
Lime (CaO)	2.57
Magnesia (MgO)	.305
Potash (K_2O)	4.07
Soda by difference (Na_2O)	2.93
Water at 110° (H_2O)	.08
Loss on ignition	.74
	99.960

Specific gravity 2.684 to 2.688.

George Steiger, chemist, of this Survey, finds that this granite contains 0.53 per cent of CaO (lime), soluble in hot dilute acetic acid, which indicates a content of 0.94 per cent of $CaCO_3$ (calcium carbonate), the presence of which is also shown by the microscope and by a slight effervescence with muriatic-acid test.

Kemp states that a cube of this stone was tested at Columbia University by boiling in dilute muriatic acid (1 part of HCl of specific gravity 1.20 to 20 parts of H_2O) for five hours, when it was found to have lost 0.59 per cent in weight. Another boiled for the same length of time in dilute sulphuric acid (1 part of H_2SO_4 of specific gravity 1.84 to 20 parts of H_2O) gave a loss of 0.48 per cent.

Absorption and crushing tests, made at the same time and place, yielded the following results: Four cubes of specific gravities 2.688, 2.687, 2.684, and 2.688, after three weeks' soaking, absorbed 0.0021, 0.0021, 0.00224, and 0.0026 per cent. The crushing test was applied to five cubes, which showed a crushing strength ranging from 25,350 to 28,841 pounds to the square inch.

The stone takes a fair polish and hammers somewhat light. The fineness of the particles precludes any marked contrast. The feldspar and quartz appear light gray, and the mica black, producing a fine mottling.

The quarry, opened in 1886, measured in 1906 about 600 feet east to west by 100 feet across and from 50 to 100 in depth.

Rock structure: The sheets are normally lenticular and horizontal, 6 inches to 30 feet thick, becoming thicker downward; but there is some irregularity in this increase in different parts of the quarry. There are two sets of joints. Those of set (a) strike N. 10° E., dip 30°–35° W., and are spaced 18 inches to 20 feet. They are intermittent and have a thin coat of discoloration, the microscopic character of which is described on page 83. Those of set (b) strike N. 80° W., are vertical, and are spaced 10 to 25 feet, exceptionally curved so as to dip as low as 55° W. On the north side a mass of fine-grained heavy, hard black schist, 40 feet thick, overlies the granite. It is traversed by horizontal and vertical quartz veins, the latter taking their rise at the contact with granite and tapering upward. Emerson [10] in one of his earlier papers on the locality represents this mass as also overlain by the granite at one end, but that part had probably been quarried away before the writer's visit in 1906. A thin section of this rock, crossing also a tortuous white veinlet, is

[10] U. S. Geol. Survey Bull. 159, fig. 16, p. 75, 1899.

found to consist, in descending order of abundance, of quartz, with sheets of cavities and rift cracks parallel to them polarizing brightly, black mica, potash feldspar (microcline), soda-lime feldspar (oligoclase), muscovite, and hornblende. Accessory: Ilmenite, titanite, pyrite, apatite, and zircon. Secondary: Epidote, carbonate, and limonite. The white veinlets are mainly quartz and soda-lime feldspar. This rock thus appears to be a quartz-mica diorite schist, but with potash feldspar apparently exceeding the soda-lime feldspar. It is an eruptive rock made schistose by pressure before the intrusion of the granite and probably formed part of the original cover into which granite was intruded. That the granite is the later rock is evident because of the marked flow structure, which, for a space of 2 feet below the diorite schist, runs parallel to the contact surface, as has been observed in some New Hampshire quarries (p. 14). This flow structure consists of parallel white bands from 0.1 to 0.3 inch wide, recurring at intervals of 1 inch. The gray granite between these light bands is darker than that beyond them. A thin section of one of these bands shows it to consist of quartz and feldspar, the quartz with many sheets of cavities up to 0.03 inch and with rift cracks parallel to them. In the darker bands biotite, epidote, titanite, and muscovite are very abundant. At the northeast corner the flowage bands have very sinuous courses, the rock taking on the appearance of a true gneiss. On the west side the flow structure, shown by a band of lighter granite 2 feet thick, strikes N. 55° E. and dips 40° SE. At the northwest corner, several feet below the granite surface, is an inclusion, 10 by 8 feet, of coarse garnetiferous muscovite-biotite gneiss with accessory magnetite, apatite, and zircon. It is a very different rock from either the granite or the diorite schist and was evidently broken off from some overlying or adjacent formation during the granite intrusion and inclosed by the molten matter.

The rift is reported as dipping about 20° W. and the grain as vertical, with a N. 10° E. course.

At the northwest corner there is a pegmatite dike (feldspar and quartz, coarse) up to 2 feet thick, with a northwest course. In thin section the feldspar is seen to be orthoclase, with fissures from 0.37 to 1.85 millimeters wide, filled with fragments of microcline and quartz and stringers of white mica. It has evidently been subjected to pressure and some metamorphism.

Rusty stain along the sheet surfaces is 3 to 12 inches thick.

Transportation, by Chester & Becket Railroad, a branch of the Boston & Albany, which connects the quarry through Walker Brook hollow with the main line at Chester, a distance of 3½ miles. The rough stone is shipped direct from the quarry; the rest is taken to the cutting shed at Chester and reshipped there. The granite thus comes to be known as "Chester granite," although the quarry is in Becket.

The product is in regular demand for monuments in Pennsylvania, New York, and Michigan. Specimens: Dr. Hoover monument, Chambersburg, Pa.; McCormack monument, Pittsburgh, Pa.; W. A. Harder monument, Hudson, N. Y.

OTIS.

The **Newall quarry** is in the town of Otis, about 2 miles west-southwest of the Hudson & Chester quarry and a mile north of Church Hill, 1,760 feet above sea level, about 3 miles northeast of Otis village. The opening is a little south of the highway from Lee and on the south side of the Lee-Huntington trolley line, with which it is connected by a siding.

The granite (specimens D, XXXIX, 234, a, b, c) is a biotite-muscovite granite of medium gray shade and of fine, inclining to medium texture, with feldspar

up to 0.2 inch. It consists, in descending order of abundance, of milk-white potash feldspar (mostly microcline with some orthoclase), pale smoky quartz, a little soda-lime feldspar (oligoclase to oligoclase-albite), black mica (biotite), and white mica (muscovite). Accessory: Pyrite, ilmenite, titanite, apatite, zircon. Secondary: Carbonate. Slight effervescence with muriatic-acid test. The stone is not identical with that of the Hudson & Chester quarry.

The quarry, opened in 1917 by Joseph Newall & Co., of Westerly, R. I., measures about 95 by 150 by 100 feet in area and from 2 to 15 feet in depth.

Rock structure: The sheets, 4 inches to 2 feet thick, are thin in the upper 8 feet. There are two sets of joints—(a), strike N. 10°–40° W., spaced 18 to 20 feet; (b), strike N. 70° E., spaced 8 to 100 feet. Flow structure strikes about north and is steeply inclined, marked by fine darker bands with whitish borders and a total width up to 0.5 inch. Dikes of pegmatite, 0.25 to 2 inches thick, have N. 80° E. and N. 30° W. courses. The rift is vertical, east-west, and the grain presumably north-south. From 100 to 200 feet east of the opening is an outcrop of plicated schist with strike N. 20° W.

The stone was used for monuments. On July 30, 1918, the quarry was idle, but in 1920 it had been reopened.

BRISTOL COUNTY.

GEOLOGIC RELATIONS.

The granites of Fall River and New Bedford, although very different, are both in a large granite area in the southeastern part of the State designated on Emerson's map in Bulletin 597 as "Dedham granodiorite (chloritic biotite granodiorite)" and are regarded as possibly of Devonian age.

FALL RIVER.

The **Beattie & Wilcox quarry** is in the city of Fall River, near Watuppa Pond and the railroad, 2½ miles southeast of the steamboat wharf. (See Fall River topographic map, U. S. Geol. Survey.) Owner, David Beattie, Fall River. Quarry not in operation.

The granite is of two colors. One (specimen D, XXX, 116, a), "Fall River pink," is a gneissoid biotite granite of medium pinkish-gray color, with black spots, and of gneissoid, coarse, inclining to medium texture, with feldspars up to 0.5 inch and mica up to 0.4 inch. Its constituents, in descending order of abundance, are pinkish microperthite (potash feldspar, orthoclase and microcline, minutely intergrown with soda-lime feldspar); milky quartz, granulated (particles mostly under 0.5 millimeter), with some cavities in sheets; milk-white soda-lime feldspar (oligoclase-albite), a little micacized and epidotized; biotite (black mica), mostly chloritized; and a little bleached biotite or muscovite. Accessory: Garnet and titanite. Secondary: Epidote, usually about the biotite, a white mica, chlorite, very little carbonate, and hematite stain. Some of the second feldspar has bent lamellae. No effervescence with muriatic-acid test.

The rock of the other color (specimen D, XXX, 116, b), "Fall River gray," is a gneissoid biotite granite of light buff-gray color, with inconspicuous black spots, and of gneissoid, medium, inclining to coarse texture, with feldspars up to 0.4 inch and mica up to 0.3 inch. Its constituents are the same as in the "pink," except that the microperthite is pale buff to pinkish, the second feldspar is light greenish, and the granulated quartz is clear and colorless, its particles measuring up to 0.75 millimeter. Among the secondary minerals is a little limonite stain. No carbonate detected nor effervescence.

These granites have in places flowage bands in which one band contains many more than the average of biotite spots, and the next contains many less and is also finer grained than the general mass, resembling an aplite.

These are very suitable granites for massive structures. The pink has more mineral contrasts than the other.

The quarry, opened in 1893, measured in 1910 about 400 by 200 feet and 10 to 40 feet deep.

Rock structure: The sheets 18 inches to 16 feet thick, undulate horizontally. Joint courses, etc., are shown in figure 71. Set (A), dip steeply N. 7° W., spaced 50 feet, forms the west-southwest wall and a heading 20 feet wide 50 feet east of it. Set (B), vertical, spaced 20 to 200 feet. The flowage bands described dip steeply S. 30° W. Shear zones dip 65° NW., are up to an inch in width, and are spaced 2 to 3 feet. The extremely fine, roughly parallel meandering planes of dark schistose material within the zones are fractures filled in their wider parts with epidote, carbonate, and muscovite. Veinlets of quartz cross the feldspars, about which there is some granulation. The lamellae of the soda-lime feldspars are much bent, and some are even minutely plicated. The rift is horizontal, and the grain dips about like the joints of set (A). A black, extremely fine-grained basaltic dike, described on page 56, is 6 inches to 4 feet thick and weathers spheroidally. The "sap" is 1 to 8 inches thick on sheet surfaces.

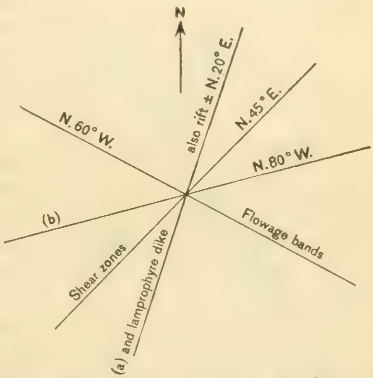


FIGURE 71.—Structure at Beattie & Wilcox quarry, Fall River, Mass.

The product met local demands mostly. Specimens: Armory, city library, Flint mills, Fall River; Bangan Chapel, in cemetery, Pawtucket, R. I.; "stone bridge" to Aquidneck Island and naval training station, Newport, R. I.

The **Beattie quarry** is in Fall River, 1½ miles west of the steamboat wharf. Operator, William H. Beattie, 33 North Quarry Street, Fall River. Idle in 1922.

The granite is of two colors. One (specimen D, XXX, 117, a), "Fall River pink," is a gneissoid biotite granite of light pinksh-gray color, with black spots, and of slightly gneissoid, coarse texture, with feldspars and mica up to 0.5 inch, the mica exceptionally reaching 0.6 inch. Its constituents, in descending order of abundance, are pinkish microperthite (potash feldspar, microcline and orthoclase, some of it epidotized, minutely intergrown with soda-lime feldspar); clear colorless quartz, granulated, with particles mostly under 0.5 inch, and with cavities, some in sheets, and rutile needles; and greenish to milk-white soda-lime feldspar (oligoclase-albite), micacized and epidotized, some of its particles with bent lamellae. Accessory: Allanite, zircon, rutile. Secondary: Fibrous muscovite stringers, another white mica, epidote, carbonate. It effervesces with muriatic-acid test.

The rock of the other color (specimen D, XXX, 117, b), "Fall River gray," is a gneissoid biotite granite of light-gray shade with conspicuous black and greenish spots, and of slightly gneissoid, coarse, inclining to medium texture. Its constituents, in descending order of abundance, are translucent grayish microperthite (potash feldspar, orthoclase and microcline, minutely intergrown with soda-lime feldspar); faintly purplish milky, quartz, granulated, with particles under 0.5 inch and with cavities; gray to pale greenish, not translucent soda-lime feldspar (oligoclase-albite), micacized and epidotized; biotite

(black mica), some chloritized, generally with epidote; and a little bleached biotite or muscovite. Accessory: Allanite, garnet, and magnetite. Secondary: Carbonate, a white mica, epidote, chlorite, and hematite stain.

These granites are very similar to those of the Beattie & Wilcox quarry, but they differ in that the pink is of lighter hue, and the gray has more marked mineral contrasts. Both pink and gray are attractive stones, well adapted for massive structures,

The quarry, opened before 1865, measured in 1910 900 by 700 feet and from 20 to 60 feet deep.

Rock structure: The sheets, 8 inches to 8 feet thick, are horizontal or dip 5°–10° SE. Joint and dike courses are shown in figure 72. Joint set (A) forms a heading 30 feet wide through the center of the quarry and is spaced 20 to 125 feet, with slickensided sericite-coated close joints parallel to it (specimen D, XXX, 117, c). Set (B), vertical, forms the south wall and is spaced about 40 feet. Set (C), vertical, forms a heading 50 feet wide diagonally through the quarry. The rift is horizontal, and the grain scarcely perceptible. A 3-inch pegmatite dike containing much quartz dips 43° N. 55° W. and has shear zones along it with small micaceous or chloritic masses. An aplite dike is 4 inches thick. Dark segregations measure up to 3 inches across. Limonite stain is up to 6 inches thick on sheet surfaces.

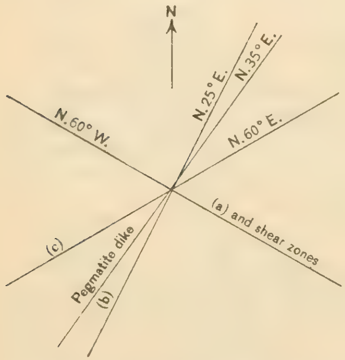


FIGURE 72.—Structure at Beattie quarry, Fall River, Mass.

Transportation, by cart 1½ miles to railroad or wharf.

The product is used mostly for buildings and wharves. The waste goes into curbing, paving, and crushed stone. Specimens: Sagamore Manufacturing Co.'s mill, wharves of Fall River Iron Works, Bristol County jail, Fall River; Bristol County courthouse (except trimmings), Taunton, Mass.; Naval War College building, Newport, R. I.

The **Savoie quarry** is on Savoie Avenue, in Fall River, 1¾ miles east-southeast of the steamboat wharf. Operator, Carey Quarry & Construction Co., Savoie Avenue, Fall River.

The granite is a gneissoid biotite granite of light-gray shade with conspicuous black and greenish spots, and of coarse inclining to medium texture, closely resembling the "gray" of the Beattie quarry.

The quarry, opened in 1895, measured in 1910 200 feet by 100 feet and 30 to 40 feet deep.

Rock structure: The sheets, 2 to 6 feet thick, are horizontal. There are four sets of joints. Set (a), vertical, strike N. 60° W. forms a heading on the north wall. Set (b), steep to vertical, strike N. 10°–20° W., forms the east and west walls and a heading 20 feet wide at the south end and is spaced 5 to 60 feet. Set (c), strike NE., dip 30° NW., only two, 12 feet apart. Set (d), diagonal, strike N. 20° E., dip 65° S. 70° E., spaced 5 to 40 feet. The rift is horizontal, and the grain vertical, with north-south course. A dark brownish-gray aplite dike, 6 inches to 2 feet thick (specimen D, XXX, 118, b), strikes east-west. There is also a pinkish apilite dike 10 feet wide (specimen 118, a.) Both these aplites are described on page 44. Quartz veins and shear zones strike N. 60° E. and dip 50° N. 30° W. There is no "sap" away from headings,

Transportation, by cart 2¼ miles to dock or rail.

The product is used for buildings, curbing, and paving, and its market is mostly local. Specimens: City library, Maple Street School (trimmings), Fall River.

The **Sears quarry** is in Fall River, about 1¼ miles east of the steamboat wharf. Operator, C. H. Sears, Fall River. Quarry abandoned.

The granite is a gneissoid biotite granite of light-gray shade with conspicuous black and greenish spots, and of coarse, inclining to medium texture, like the "gray" of the Beattie quarry (p. 283).

The quarry, opened in 1892, measured in 1910 125 by 75 feet and 20 feet deep.

Rock structure: The sheets, 1 to 8 feet thick, undulate. There are two sets of joints. (Set (*a*), about east-west, forms the north wall and a heading 15 feet wide through the center of the quarry and is spaced 2 to 20 feet. Set (*b*), nearly north-south, forms the west wall and is spaced 10 to 20 feet but in places crosses one sheet only. The rift is horizontal and the grain vertical, north-south, but scarcely perceptible. There is little "sap" away from headings.

Transportation, by cart.

The product was used for local buildings. Specimen: Lower story of Textile School, Fall River.

The **Stinziano quarry** is at the corner of Locust and Oak Grove avenues, Fall River. Operator, Fall River Granite & Quarry Co., Fall River.

The granite is essentially like that of the other Fall River quarries.

The product is dressed stone for buildings and pedestals, also paving and foundations.

The **Ross quarry** is at the head of Barlow Street, near Watuppa Pond, in Fall River, 2¾ miles about southeast of the steamboat wharf. (See topographic map of Fall River quadrangle, U. S. Geol. Survey.) No longer operated.

The granite (specimen D, XXX, 119, a), "Fall River, Barlow Street," is a gneissoid biotite granite of medium bluish-gray color and of medium texture, with feldspars up to 0.3 inch and mica up to 0.1 inch. Its constituents, in descending order of abundance, are pinkish cloudy microperthite (potash feldspar, orthoclase and microcline, minutely intergrown with soda feldspar); clear colorless quartz, granulated, with particles nearly all under 0.5 millimeter; clear colorless to pale-greenish soda feldspar (albite), micacized and epidotized; and biotite (black mica), some of it chloritized, associated with epidote and a little muscovite or bleached biotite. Accessory: Garnet. Secondary: Muscovite in stringers, also a white mica in the albite, epidote, carbonate, and chlorite. No effervescence with muriatic-acid test.

As will be noticed from the description, this stone differs from the other Fall River gray granites in the absence of the large black micas. The second feldspar here is pure albite. The mineral contrasts are feeble.

The quarry, opened before 1901, measured in 1910 125 feet square and 30 feet deep.

Rock structure: The sheets, 1 to 5 feet thick on the east side, are lacking on the west side. There is only one joint, striking east-west and forming the south wall. The upper sheets are badly discolored.

The product was curbing, flagging, and paving.

NEW BEDFORD.

The **Sullivan quarries** are near Rockdale, in the township of New Bedford, 2 miles northwest of the city. (See New Bedford topographic map, U. S. Geol. Survey, and Pl. XXIII.) Operator, Sullivan Granite & Construction Co., New Bedford.

The granite (specimens D, XXX, 121, a, pinkish, and b, less pinkish), "New Bedford," is a biotite-muscovite granite gneiss of light pinkish-gray color and of slightly gneissoid, coarse inclining to medium texture, with feldspars up to 0.5 inch and mica up to 0.1 inch. Its constituents, in descending order of abundance, are light-pinkish potash feldspar (microcline), some of it slightly kaolinized; medium smoky quartz with cavities and black particles in parallel sheets; milky soda-lime feldspar (oligoclase-albite); biotite (black mica), some of it chloritized; and muscovite (white mica). Accessory: Garnet, magnetite, fluorite, apatite, and zircon. Secondary: Kaolin, epidote, chlorite, and limonite. No carbonate or pyrite detected. No effervescence with muriatic-acid test.

This is an attractive and substantial building stone. Its mineral contrasts are a little more marked than those of the "Dartmouth granite." The absence or scarcity of pyrite and carbonate is in its favor.

The quarries comprise two openings. The main one, begun about 1860, was in 1910 600 by 150 feet and from 50 to 75 feet deep. The other, about 300 feet farther south, formerly known as the Denault quarry, was about 250 by 150 feet and from 50 to 70 feet deep.

Rock structure: Dike, joint, and grain courses are shown in figure 4 (p. 55). The sheets in the main quarry are 10 to 25 feet thick, but for a space of 5 or 6 feet on either side of the dikes there are sheets 3 to 18 inches thick, which were evidently formed after the dikes and largely in consequence of them. There are two sets of joints. Set (a), coated with epidote, is vertical and spaced 50 feet. Set (b), confined to the Denault quarry, dips 55° E., is spaced 2 to 30 feet, with a heading at east wall and another 10 to 18 feet wide near it. The rift is horizontal. The dikes have been described on pages 55–56. There is one each on the north, south, and west walls, through the center, and another of pegmatite near the west wall. The amount of rusty stain is small.

Transportation, by cart 2 or 3 miles to New Bedford.

The product is used for local buildings and streets. Specimens: Armory, public library (90 per cent, the rest being from Fall River quarries), St. James and St. John Roman Catholic churches, and trimmings to most of the cotton mills, New Bedford.

DARTMOUTH.

The **Dartmouth quarry** is in Dartmouth Township, three-fourths of a mile east of Westport Mills and 8¼ miles southeast of the Fall River steamboat wharf. (See Fall River topographic map, U. S. Geol. Survey, and Pl. XXIII.) Operator, New Bedford & Dartmouth Granite Co., New Bedford.

The granite (specimen D, XXX, 122, a), "Dartmouth," is a gneissoid biotite-muscovite granite of very light buff-gray color and of very slightly gneissoid, medium, inclining to coarse texture, with feldspars up to 0.5 inch and mica up to 0.1 inch. Its constituents, in descending order of abundance, are translucent cream-colored microperthite (potash feldspar, microcline, minutely intergrown with lime-soda feldspar, oligoclase-albite, and somewhat kaolinized); pale, smoky quartz, with cavities, in sheets; clear to translucent soda-lime feldspar (oligoclase-albite), but little kaolinized; and muscovite (white mica) and biotite (black mica) in about equal amounts. Accessory: Garnet. Secondary: Kaolin and carbonate. Very little effervescence with muriatic-acid test. This is a serviceable constructional stone of feeble mineral contrasts.

The quarry, opened in 1903, was in 1910 about 150 by 100 feet and 30 feet deep, with a working face 45 feet high on the west.

Rock structure: The sheets, 1 to 12 feet thick, are about horizontal. The joints, all discontinuous, are of three sets—(*a*), strike N. 75° E., dip 75° S. 15° E., on north and south walls only; (*b*), strike north, dip 50° E., spaced 3 to 10

feet; forms the west wall; (*c*), strike N. 25° W., dip 65° N. 65° E., one only. The rift is horizontal and the grain vertical, with N. 60° E. course. There are small pegmatite and smoky quartz dikes with N. 60° W. courses. Rusty stain is up to 3 inches thick on sheet surfaces, diminishing at the bottom of the quarry.

The product is used for local buildings, curbing, and paving. Specimen: Trimmings on Lunds Corner schoolhouse, New Bedford.

ESSEX COUNTY.

PEABODY-LYNNFIELD DISTRICT.

GEOLOGIC RELATIONS.

The granites of the Peabody-Lynnfield district are in a granite area designated on the geologic map of the State[11] in Bulletin 597 as "Quincy granite (soda-rich riebeckite granite)."

The granite is an olive-greenish hornblende-augite granite resembling the riebeckite-aegirite granite of Quincy, but its black silicates contain very little soda. Washington[12] refers to the stone in these words:

"The rocks belonging to this class were first noticed by Wadsworth in 1885 and were later described more in detail by Sears. Rosenbusch has expressed the opinion that these are related to the akerite type of syenites, a keen observation which my study of the rocks fully confirms. These rocks are found chiefly in the eastern part of Essex County, in Essex, Beverly, Manchester, Gloucester, and on Cape Ann. * * * The color even of the freshest specimens is greenish, which varies in shade from a dark greenish black to a light shade of greenish gray."

In common with the green granite of Redstone, N. H., described on page 168, that of Peabody and Lynnfield contains considerable allanite, to the oxidation of which the green color is partly due. (See further p. 77.)

QUARRIES.

The **Linehan quarry** is in Peabody Township, on a knoll one-fourth mile east of Bartholomew Pond, about 3 miles west-southwest of Peabody. (See Salem topographic map, U. S. Geol. Survey and Pl. XXIII.) Operator, John Dubie, Peabody. Quarry abandoned.

The granite (specimen D, XXX, 128, a), "Peabody green," is a hornblende-augite granite of very dark olive-greenish color and of even-grained, coarse texture, with feldspars up to 0.7 inch and black silicates up to 0.2 inch. Its constituents, in descending order of abundance, are dark olive-greenish microperthite (potash feldspar, orthoclase, minutely intergrown with plagioclase, probably soda feldspar, kaolinized and with crush borders); very dark greenish smoky quartz, with cavities in sheets intersecting, some at right angles, and with cracks filled with limonite stain; green hornblende; and augite intergrown with or passing into the hornblende. Accessory: Magnetite, allanite, rather plentiful zircon, and apatite needles. Secondary: Kaolin, limonite stain, and carbonate. Slight effervescence with muriatic-acid test.

This granite differs from the green of the Robin Rock quarry (p. 289) only in its more yellowish tinge. When first quarried it is grayish, but within a week it becomes yellowish green.

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[11] Emerson, B. K., op. cit., pp. 188, 189.

[12] Washington, H. S., The petrographical province of Essex County, Mass.: Jour. Geology, vol. 6, p. 787, 1898. See also Sears, J. H., The physical geography, geology, mineralogy, and paleontology of Essex County, Mass., pp. 178, 190, Salem, Mass., 1905.

The quarry, opened in 1900, measured in 1910 250 feet east and west by 80 and 100 feet across and 20 to 40 feet deep.

Rock structure: The sheets, 8 to 16 feet thick, are lenticular and horizontal. There are two sets of joints—(*a*), vertical, strike N. 15° E., on east and west walls only, 250 feet apart; (*b*), "rift joints," diagonal, strike N. 70° E., dip 65° S. 20° E., coated black with hornblende,[13] also with calcite up to 0.12 inch thick, spaced 30 to 60 feet. The rift, which is marked, is parallel to set (*b*); the grain is at right angles to it, and the hardway horizontal. Dark-gray knots are 0.5 inch to 12 inches across. The stain forms a dark-brown surface on the sheets, with an inch of pale granite below it; in places, however, the brown part is an inch thick and the pale granite 2 inches. The joints are also discolored in this way.

Transportation, by cart, an average of 3 miles.

The product is used for street work and trimmings. Specimen: Trimmings on addition to Mercantile Bank, Salem.

The **Caron quarry** is in Peabody Township, about a quarter of a mile south-southeast of the town farm on Lynnfield Street. (See Salem topographic map, U. S. Geol. Survey.) Operators, M. Caron & Sons, 32 Perkins Street, Salem. Quarry abandoned.

The granite, "Peabody green," is a hornblende-augite granite of very dark olive-greenish color and of even-grained, coarse texture like that of the Linehan quarry, described on page 287.

The quarry, opened in 1898, measured in 1910 75 by 30 feet and from 10 to 30 feet deep.

Rock structure: This is a "boulder quarry" yielding blocks 18 feet thick. There are two sets of joints—(*a*), strike N. 77° E., dip 60° S. 13° E., spaced 10 to 20 feet; (*b*), strike N. 40° E., dip 50° N. 50° W., spaced over 30 feet. The rift is parallel to set (*a*) and the grain dips 70° about west. The "sap" is up to 3 inches thick on masses below the surface, half of it being brown.

Transportation, by cart.

The product is used for trimmings and curbing. Specimens: Trimmings on hotel at corner of Mill and Washington Streets, and on store at corner of Derby and Dinell Streets, Salem.

The **Den quarry** is on the Peabody and Lynn town line, about 2¾ miles north-northwest of Lynn station. (See Boston Bay topographic map, U. S. Geol. Survey.) Operator, C. E. Mudge, Lynn. Idle since 1912.

The granite (specimens D, XXX, 126, a, b), "Peabody green," is a hornblende-augite granite of dark to very dark olive-greenish color. When first quarried the feldspars are less greenish and lighter and the general color corresponds, but this soon changes. Its texture is even grained, coarse, with feldspars up to 0.7 inch and black silicates up to 0.4 inch. Its constituents, in descending order of abundance, are medium but soon becoming dark greenish-gray microperthite (potash feldspar (orthoclase), minutely intergrown with soda feldspar (albite), much kaolinized, with crush borders and with cracks filled with limonite stain); very dark yellow-greenish smoky quartz, with cavities in sheets, some intersecting at right angles, and with cracks parallel to them and filled with limonite stain; black hornblende (green in section), with inclusions of allanite; and black augite (green in section), intergrown with or passing into the hornblende, also with inclusions of allanite. Accessory: Magnetite, allanite, zircon, apatite, and very little biotite. Secondary: Limonite stain proceeding from the allanite and augite and following the boundaries of particles and

[13] These black-coated joints signify metamorphism after the jointing. See p. 82.

cracks, kaolin. a brown and also a blue hornblende (probably riebeckite) in fibrous crystals growing out of the augite surfaces into quartz and feldspars, and carbonate. Slight effervesence with muriatic-acid test.

This stone is reported as taking a good polish, which might be expected from its lack of mica.

The quarry, opened about 1905, measured in 1910 about 100 feet square and 20 to 60 feet deep.

Rock structure: The sheets, 16 to over 30 feet thick, dip 20° S. 55° E. There are four sets of joints—(*a*), discontinuous, strike N. 5° E., dip 75° E., forms a heading on east wall, spaced 30 to 40 feet; (*b*), vertical, strike east, forms a heading 100 feet wide on east wall, spaced 25 to 40 feet; (*c*), strike N. 40° W., dip 47° S. 50° W., one only; (*d*), vertical, strike N. 30° W., one only. The rift dips steeply S. 60° W., and the grain, which is almost as pronounced as the rift, is horizontal. Very dark gray segregations (knots) are up to 0.5 inch, exceptionally 2 feet across. A thin section of one of these knots (specimen D, XXX, 126, d) shows a groundmass of particles of microperthite and plagioclase (probably albite) from 0.1 to 0.3 millimeter in diameter, with thickly disseminated particles of augite from 0.02 to 0.37 millimeter, and minute grains of magnetite. At the edge is a large porphyritic microperthite, a crystal of zircon, and a particle of augite associated with a blue hornblende, biotite, magnetite, and zircon.

The feldspars on the sheet surfaces are generally much kaolinized. The rusty stain (specimen D, XXX, 126, c) is up to an inch thick, and the pale-green band below it from 2 to 4 inches. A top sheet, 12 feet thick and 100 by 40 feet in area, is all discolored.

Transportation, by cart.

The product is used for base courses, steps, curbing, crossings, caps, and paving. The rusty faces are used for base courses. Specimens: Starr Parsons Monument, in Pine Grove Cemetery, and sap-faced base course of dwelling at corner of Wave and Ocean streets, Lynn.

The **Robin Rock quarry** is in Lynnfield Township, four-fifths of a mile south-southeast of South Lynnfield station. (See Lawrence topographic map, U. S. Geol. Survey.) This quarry was operated by the late Arthur L. Kallenberg, of Lynnfield, and may be operated again by his son.

The granite (specimen D, XXX, 127, a), "Robin Rock green," is a hornblende-augite granite of very dark greenish color and of coarse, even-grained texture, with feldspars up to 0.6 inch and black silicates up to 0.4 inch. Its constituents, in descending order of abundance, are dark-blue or greenish-gray microperthite (potash feldspar, orthoclase, minutely intergrown with soda feldspar, albite, and kaolinized); very dark, slightly greenish smoky quartz, with cavities in sheets intersecting at right angles; black (under the microscope greenish) hornblende with inclusions of allanite; very little separate soda feldspar (albite); and black (under the microscope greenish) augite. Accessory: Magnetite, allanite, pyrite, zircon, and a little biotite. Secondary: Kaolin and limonite stain. No effervescence with muriatic-acid test.

Another variety (specimen D, XXX, 127, b), "Robin Rock gray," is also a hornblende-augite granite but of dark-gray shade, speckled with black, and of coarse, even-grained texture, with feldspars up to 0.7 inch and black silicates up to 0.3 inch. Its constituents appear to be the same as those of the other variety, but, as shown by effervescence with acid test, carbonate is present. The microperthite is dark gray in the hand specimen but shows some limonite-

stained faces. Augite is intergrown with hornblende or passes into it. Apatite appears among the accessory minerals, and zircon is rather plentiful. This stone probably becomes somewhat greenish on continued exposure.

This stone appears well when fine pointed.

FIGURE 73.—Map of part of Cape Ann, Mass., showing the location of Rockport granite quarries. 1, Flat Ledge quarry; 2, upper pit, Rockport Granite Co.; 3, lower Pigeon Hill quarry; 4, upper Pigeon Hill quarry; 5, Babson Farm quarry; 6, Nickerson quarry; 7, Breakwater quarry; 8, Canney quarry; 9, Devils Rock quarry; 10, Cheves Green Granite quarry; 11, Blood Ledge quarry; 12, deep pit, Rockport Granite Co.

There are several openings, some of which are a century old. The one worked in 1910 was triangular in area, 75 feet on a side and 5 to 25 feet deep.

Rock structure: The sheets, 18 inches to 6 feet thick, dip 10° E. There is only one set of joints, vertical, strike N. 80° W., spaced 3 to 12 feet, with a

heading 15 feet wide on the north side. The rift is vertical, with east-west course, and the grain vertical, north-south. "Knots" measure up to 6 inches. The stain on sheet surfaces is yellowish for an inch, then for 2 inches the stone is pale.

Transportation, by cart 4 to 6 miles to Wakefield and Reading.

The product was used for buildings, foundations, sills, steps, and curbing.

ROCKPORT.

TOPOGRAPHY.

The township of Rockport occupies the eastern and northern part of that insular mass on the Atlantic coast commonly known as Cape Ann. (See Gloucester topographic map, U. S. Geological Survey.) It is a region of low, roundish or oval granitic or sandy hillocks, none exceeding 180 feet in height, and of marshes and boulder-strewn sand flats. The most conspicuous of these hillocks is Pigeon Hill, about a mile north of Rockport village, which is regarded as a drumlin. The quarries are in the northern part of the cape, scattered along the shore or within three-quarters of a mile of it, from Rockport to Bay View. (See fig. 73.)

GEOLOGIC RELATIONS.

The physiography and geology of Cape Ann have been interestingly described by Shaler and Tarr.

The entire cape is represented in Shaler's map[14] as made up of granite, but traversed at very close intervals by diabase dikes and at a few points by quartz porphyry dikes. According to Sears's geologic map of Essex County, hornblende granite covers Halibut Point, Rockport, and the area half a mile east of Bay View; but a quarter of a mile east of Bay View there is a small area of "augite syenite."[15]

Emerson[16] on the geologic map of the State shows the cape as a part of a large area of "Quincy granite" (soda-rich riebeckite-bearing granite but with a small area of Beverly syenite just north of Pigeon Cove and another about Lanesville, neither of which, however, is quarried.

The geologic age of the granite is regarded as Carboniferous. The basic dikes may be Triassic. They range from 0.5 inch to 40 feet in width.

"ROCKPORT GRANITE."

The more recent scientific accounts of "Rockport granite" are those of Wadsworth,[17] Merrill,[18] Washington,[19] Sears,[20] and Clapp.[21] Cooke,[22] Clarke,[23] and

[14] Shaler, N. S., The geology of Cape Ann, Mass.: U. S. Geol. Survey Ninth Ann. Rept., pp. 529–611, pl. 77, 1889.

[15] Sears, J. H., The physical geography, geology, mineralogy, and paleontology of Essex County, Mass., Salem, Essex Institute, 1905.

[16] U. S. Geol. Survey Bull. 597, pl. 10, pp. 188, 189, 197, 1917.

[17] Wadsworth, M. E., Notes on the petrography of Quincy and Rockport: Boston Soc. Nat. Hist. Proc., vol. 19, 1881.

[18] Merrill, G. P., Smithsonian Inst. Rept. for 1885, pt. 2, p. 419, 1889.

[19] Washington, H. S., The petrographical province of Essex County, Mass.: Jour. Geology, vol. 6, pp. 790–796, 1898.

[20] Sears, J. H., op. cit., pp. 150–153.

[21] Clapp, C. H., Igneous rocks of Essex County, Mass., 1910; Geology of the igneous rocks of Essex County, Mass.: U. S. Geol. Survey Bull. 704, 1921.

[22] Cooke, J. P., On cryophyllite, a new mineral species of the mica family with some associated minerals in the granite of Rockport, Mass.: Am. Jour. Sci., 2d ser., vol. 43, pp. 217–230, 1867; On danalite from Rockport: Idem, 2d ser., vol. 42, p. 73, 1866.

[23] Clarke, F. W., On cryophyllite from Rockport: Idem, 3d ser., vol. 32, p. 358, 1886.

Penfield and Forbes[24] have described certain new or unusual minerals in "Rockport granite."

The following epitomizes the descriptions of rough and polished specimens and thin sections of this granite from all the quarries as given in the succeeding pages. Analyses, mineral percentages, and results of physical tests follow the description.

"Rockport granite" is of two sorts. The more abundant, known commercially as "gray granite," is a hornblende granite of medium-gray shade (in places with slight greenish or bluish tinge) spotted with black. Its texture is medium to coarse and even grained, with feldspars up to 0.3 or 0.5 inch and hornblende up to 0.2 inch. Its constituents, in descending order of abundance, are a light-gray potash feldspar (orthoclase with or without microcline) of a slightly greenish or bluish or buff tinge, generally twinned and minutely intergrown with soda-lime feldspar (albite to oligoclase-albite), more or less kaolinized; smoky quartz with abundant cavities (many with liquid and vacuoles), from 0.0043 millimeter or less to 0.02 millimeter in diameter, mostly in sheets: black hornblende, in places with a little bluish-black riebeckite (p. 317); very little separate soda-lime feldspar like that described above; and very little black mica (biotite or lepidomelane).[25] Accessory: Magnetite, pyrite, allanite, fluorite, zircon, apatite. Secondary: Hematite, limonite, kaolin, some black hornblende, calcite.

Estimates of the mineral percentages by the Rosiwal method yield these results: Feldspar, 55.50 to 59.60, average 57.97; quartz, 33.88 to 38.90, average, 35.82; hornblende and mica, 5.60 to 7.26, average, 6.20.

"Rockport granite" is said to be "hard." These estimates show quartz averaging 35.83 per cent, or if the green of Bay View, given beyond, is averaged with the gray, 34.85 per cent, whereas the average amount of quartz in five tests of Quincy granite is 30.60 per cent (p. 318), in "Conway" red granites 28.62 per cent (p. 166), and in the "Redstone granite" of Westerly, R. I. (p. 413), 29.87 per cent. This extra 6 per cent of quartz may be sufficient to account for the hardness.

H. S. Washington[26] gives the following analysis of "Rockport granite":

Analysis of "Rockport granite."

[H. S. Washington, analyst.]

Silica (SiO_2)	77.61
Titanium dioxide (TiO_2)	.25
Alumina (Al_2O_3)	11.94
Iron sesquioxide (Fe_2O_3)	.55
Iron oxide (FeO)	.87
Manganese oxide (MnO)	Trace.
Magnesia (MgO)	Trace.
Lime (CaO)	.31
Soda (Na_2O)	3.80

[24] Penfield, S. L., and Forbes, E. H., Fayalite from Rockport, Mass., etc.: Am. Jour. Sci., 4th ser., vol. 1, pp. 129–131, 1896.

[25] H. S. Washington (op. cit., p. 793) reports two varieties of biotite, one very pale green, probably cryophyllite of Cooke, the other darker greenish gray, lepidomelane (annite). F. W. Clarke (op. cit.) shows that several varieties of biotite occur.

[26] Op. cit., p. 793. On p. 794 he gives these estimates of the mineral percentages, based partly on the analysis and partly on microscopic observation: Feldspar 50.2 per cent, quartz 35.5 per cent, hornblende and two biotites 3.8 per cent, accessory minerals 0.5 per cent. The figure for quartz agrees very closely with that obtained by the Rosiwal method.

Potash (K_2O)	4.98
Water (H_2O) at 110°—	Trace.
Water (H_2O) at 110°+ignition	.23
	100.54

Specific gravity 2.618 at 18° C.

Messrs. Steiger and Sullivan, chemists, of this Survey, find that this granite contains from 0.14 to 0.20 per cent of CaO (lime) soluble in hot dilute acetic acid, which indicates the presence of 0.25 to 0.35 per cent of $CaCO_3$ (calcium carbonate calcite). (See pp. 294, 296.)

Because the black silicate is almost entirely hornblende the stone takes a very high polish. The contrasts of shade between the gray feldspar, smoky quartz, and black hornblende are much more marked on the polished than on the rough face.

The other variety of "Rockport granite," known as "green granite," is also a hornblende granite but of somewhat dark olive color spotted with black. Its texture is medium to coarse, even grained, with feldspars up to 0.3 and 0.5 inch and hornblende up to 0.2 inch. Its constituents, in descending order of abundance, are medium olive-gray feldspars, like those of the gray variety, slightly yellow-greenish smoky quartz, black hornblende and biotite (black mica), together with accessory magnetite, zircon, and allanite, and secondary kaolin, limonite, and calcite. The feldspar varies in the same particle from an olive-green to a scarcely greenish milk-white. Limonitic stain is visible in the rift and other cracks of both feldspar and quartz. This stain seems to originate in particles of allanite and magnetite, in the biotite and hornblende, and partly in minute ferruginous particles in the feldspars. Quarrymen state that this stone, which when first quarried is a dark gray, becomes greenish after an exposure of three or four hours to rain. It is also stated that the green granite loses some of its color on continued exposure about the quarry. Specimens of this slightly faded green granite show that, while the feldspars have lost a little of their greenness, that color is preserved in the quartz.

An estimate of the mineral percentages in this granite by the Rosiwal method yields the following results: Feldspars, 58.45; quartz, 31.95; hornblende, 9.60.

This granite takes as high a polish as the gray, but its contrasts are less marked.

Besides these granites there is near Bay View a dark brownish-gray riebeckite-aegirite-biotite granite, which has only been prospected and is described on page 302, and also near Pigeon Cove a beautiful diabase porphyry, as yet little worked, described on page 303. The bright rust-colored "sap" referred to on page 67 is unusually abundant in some of the Rockport quarries. This brightly discolored granite has been used by architects in the basements of several private residences on the Cape. The offices of the Rockport Granite Co. and the Rockport Carnegie Library are made of it. In both buildings the fresh gray granite has been used for trimmings. The resulting contrast is pleasing.

GEOLOGY OF ROCKPORT QUARRIES.

The conspicuous feature of the Rockport quarries is the large number of basic dikes which traverse them. Some of these are shown in plate XXVII, *A*, *B*. Their courses are given in the quarry descriptions. One attains a thickness of 18 feet. The dike matter was erupted through deeply parted joints. Contemporaneous with the dikes was the irregular-shaped injection de-

scribed on page 54 and shown in Plate XXVII, *B*, and figure 3. The faulting of the large dike in the same quarry shows that a crustal movement affected the region after the crystallization of the dike material. The injection of molten matter into cold granite was not without effect, for the stone on either side of these dikes is likely to be darkened. (See p. 57.)

The pegmatite dikes contain some bright-green feldspar (amazon stone). A 4-inch dike of aplite is bordered by pegmatite 1 to 2 inches thick.

Segregations (knots) are not uncommon in "Rockport granite," but at Halibut Point, the extreme north end of the cape, in the Babson Farm quarry, there is one of unusual character. It is 8 by 4 by 2½ feet and consists mainly of feldspar and quartz. (See further p. 60.)

Although some of the data obtained from the quarrymen as to rift and grain appear to be incorrect, owing to their confounding rift and grain or else to inaccurate observation, the course of the rift appears to be east-west and generally vertical and the grain horizontal. Rift and grain cracks can be detected in the quartz areas of polished surfaces.

Sheet structure is generally imperfect, owing either to the shortening of the lenses by increase in the curvature of the fractures or to the low-dipping joints which intersect them, or else to incomplete development. In some places the "toe-nail structure" enhances the difficulties.

The joints at the 11 quarries in operation in 1906 have the following courses: About north, N. 25° E., N. 30°–40° E., N. 60°–75° E.; about east, N. 15°–20° W., N. 30°–45° W., and N. 55°–70° W. The courses noted at the largest number of quarries were N. 30°–40° E., N. 30°–40° W., N 60°–75° E., and east.

At the upper Pigeon Hill quarry a compressive strain in all lateral directions results in undulating fractures and binds the chisels in channeling.

QUARRIES.

The **Flat Ledge quarry** is half a mile north-northwest of Rockport and 80 feet west of Sandy Bay. (See fig. 73.) Operator, Rockport Granite Co., Rockport.

The granite (specimens D, XXVIII, 24, a, f), "Rockport light gray," is a hornblende granite of medium gray, slightly bluish-green color with inconspicuous black spots. In large masses its general color is bluish gray. Its texture is medium to coarse, even grained, with feldspars up to 0.5 inch and hornblende to 0.2 inch. Its constituents, in descending order of abundance, are a light-gray, slightly blue-greenish potash feldspar (orthoclase, some of it twinned and microcline), minutely intergrown with soda-lime feldspar and somewhat kaolinized; very smoky quartz; black hornblende; and very little separate soda-lime feldspar (oligoclase-albite); together with accessory magnetite, molybdenite, purple fluorite, and zircon and secondary kaolin and calcite.

George Steiger, a chemist of this Survey, finds that it contains 0.20 per cent of CaO (lime) soluble in hot dilute acteic acid, which indicates the presence of 0.35 per cent of $CaCO_3$ (calcium carbonate, calcite).

The stone takes a very high polish and hammers somewhat light.

The quarry, opened about 1855, measures about 1,100 feet from northwest to southeast by 1,000 feet across and 125 feet in depth.

Rock structure: The sheets, 6 inches to 30 feet thick, are horizontal in the southern part, dip 25° NW. on the east side, and dip about 20° S. in the center. One set of joints, strike N. 15° W., dip 65° WSW., is spaced 8 to 15 feet. Another set, strike N. 60° W., dip 80° NNE., is spaced 2 to 25 feet. The rift is reported as dipping 20° about south, and the grain as vertical, with a N. 15°–20° E. course. A medium-grained pegmatite dike, 5 feet thick, strike N.

30° W., dip 25° E., consists of potash feldspar (microcline and orthoclase), smoky quartz, soda-lime feldspar (oligoclase to andesine), garnet, and zircon. A coarse-grained dike, not examined microscopically, consists of a cream-colored feldspar, in places bright green, smoky quartz, black and possibly other varieties of mica, and garnets. Basic dikes strike N. 10° E., N. 15° W., and N. 60° W., dipping 40°, 70°, and 90°. The discolored granite adjacent to one of these was examined and has been described on page 58. Rusty stain, 0.25 to 2 inches thick, is very abundant and bright, particularly along the joint faces. (See pp. 67–69.)

Transportation, by an 800-foot track to cutting shed and wharf.

Product of this and other Rockport quarries of this company yielding gray granite—specimens: Fox Hill bridge, Lynn; courthouse, Worcester; Y. M. C. A. Building and customhouse, Boston; Masonic Temple, Champaign, Cook County Hospital, Chicago; Tyler monument, Richmond, Va.

The **"Upper pit" of the Rockport Granite Co.** lies west-southwest of the Flat Ledge quarry, about half a mile northwest of Rockport. (See fig. 73.) Operator, Rockport Granite Co., Rockport.

The granite, "Rockport light gray," is a hornblende granite identical with that of the Flat Ledge quarry.

An estimate of the mineral percentage in this stone, made by the Rosiwal method, with half-inch mesh and total linear length of 20 inches, yielded the following results: Feldspars, 55.50; quartz, 38.90; hornblende, 5.60.

The quarry measures about 625 feet from northwest to southeast by 325 feet across; an intermediate opening, 150 by 125 feet, averages 100 feet in depth.

Rock structure: The sheets, 4 to 35 feet thick, dip 20° about east. One set of joints, strike N. 30° E., dip 50° W., is spaced down to 10 feet; another, strike about N. 30° W., dip 30°–50° E., is spaced down to 5 feet. A third set, in the intermediate opening, strike N. 70° E., dip steeply south-southeast, is spaced 10 to 25 feet. A fourth set, "blind seams," strike east, dip 50° S., recurs at very irregular intervals and is unstained. The rift is reported as striking N. 80° W. and dipping 75°–80° S. The grain is probably like that in the Flat Ledge quarry. There are four basic dikes on the east and west sides, striking N. 15° W. and dipping 70° E., and an 8-foot dike in the smaller opening striking N. 70° W. and dipping steeply north-northeast. A dike of aplite, 4 inches wide, with a border of pegmatite 1 to 2 inches thick with bright-green feldspar, strike N. 55° E. Gray knots measure up to 12 inches.

Transportation, by track 1,500 feet to wharf.

In 1906 this quarry was furnishing part of the granite for the piers and tower of the Cambridge-Boston bridge over Charles River, and also for the anchorage of Manhattan Bridge No. 3 on the New York side.

The **lower Pigeon Hill quarry** is at the south foot of Pigeon Hill, one-third mile west of the shore and 1 mile north-northwest of Rockport. (See fig. 73.) Operator, Rockport Granite Co., Rockport.

The granite (specimens D, XXVIII, 34, a, b), "Rockport light gray," is a hornblende granite of medium-gray, slightly bluish-green color, and inconspicuous black spots. Its texture is medium to coarse and even grained. In texture, general color, and constituents this stone appears to be identical with that of the Flat Ledge and "upper pit" of the Rockport Granite Co. The only discernible difference is that the Pigeon Hill stone shows less quartz and a slightly lighter shade in the feldspar. The thin sections also show the presence along with the black hornblende of a littlle blue-black riebeckite (soda hornblende) and a little biotite (black mica). Allanite, apatite, and

pyrite appear also among the accessories. There is some secondary brown hornblende filling microscopic cracks in the feldspar, also a little secondary hematite and limonite stain. Some cavities of irregular outline in the quartz measure up to 0.02 millimeter; others, of oval or roundish form with liquid and vacuoles, measure up to 0.0043 millimeter.

An estimate of the mineral percentages in this granite, made by the Rosiwal method, with half-inch mesh and a total linear length of 30 inches, yields the following results: Feldspars, 58.86; quartz, 33.88; hornblende, 7.26.

A chemical analysis of this stone, by H. S. Washington, is given on page 292. E. C. Sullivan, a chemist of this Survey, finds that it contains 0.14 per cent of CaO (lime) soluble in hot dilute acetic acid, which indicates a content of 0.25 per cent of $CaCO_3$ (calcium carbonate, calcite).

The following data as to this granite were obtained by tests made at the United States Arsenal at Watertown, Mass., in 1894 from stone quarried during the previous month:

Compressive strength: Tests 6871, 6872, 6870 (cubes about 4 inches square). First crack at 79,000, 86,000, and 94,000 pounds; ultimate compressive strength,

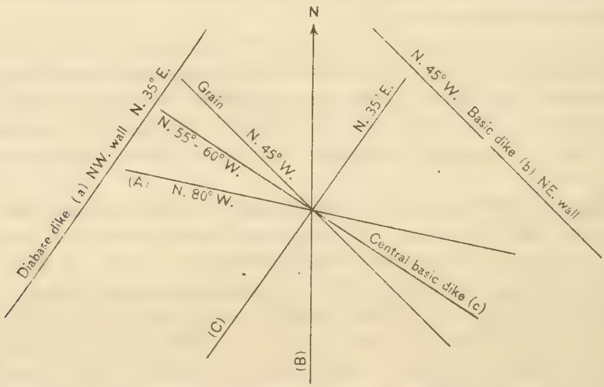

FIGURE 74.—Structure at lower Pigeon Hill quarry, Rockport, Mass.

20,716, 20,522, and 17,772 pounds to the square inch. Direction of rift and grain in cubes not given.

Compressive elastic strength: The block tested measured 24 by 4.01 by 6.06 inches; weight, 54.5 pounds; weight per cubic foot, 161.5 pounds; sectional area, 24.3 inches square. Pressure applied endwise. Under a pressure of 1,000 pounds to the square inch, the compression in a gaged length of 20 inches was 0.0031 inch; under 2,000 pounds, from 0.0063 to 0.0078 inch; under 4,000 pounds, from 0.0116 to 0.0129 inch; under 6,000 pounds, from 0.0162 to 0.0175 inch; under 8,000 pounds, from 0.0208 to 0.0209 inch; under 10,000 pounds, from 0.0253 to 0.0258 inch; and under 12,000 pounds, 0.0297 inch.

Shearing strength: Dimensions of block, 12 by 6 by 4 inches; distance apart of supports, 6 inches; width of plunger, 5 inches. Tests, 6879, 6880. First tension fractures midway between supports at 45,400 and 38,600 pounds. Shearing fractures developed later near edge of one support. Shearing strength, 2,047 and 1,052 pounds to the square inch of shearing area.

Transverse strength: Dimensions of block, length, 24 inches; width, 6 inches; breadth, 4 inches (decimals omitted); length between end supports, 19 inches; tests, 6882, 6883; ultimate strength, 12,320 and 12,480 pounds to the square

inch, equaling a modulus of rupture of 2,404 and 2,416, respectively. This was computed by the formula

$$R=\frac{3pl}{2bd^2}$$

The granite takes a very high polish and hammers rather light.

The quarry, opened about 1871, measured in 1906 about 625 feet on the northeast side and 700 feet on the southwest side by 450 to 500 feet across and from 40 to 80 feet in depth.

Rock structure: The sheets, 6 to 10 feet thick, dip about 10° NE. in the northern part of the quarry but 10°–30° SE. in the southeastern part. The joint and dike courses are shown in figure 74. Set (A), dip 75° N., spaced 3 to 10 feet, abounds in the southern part. (B), dip 55° W., exceptionally 55° E., spaced 2 to 20 feet. In the southwestern part the closeness of these joints precludes the quarrying of large blocks. (C), dip steeply west. The rift is reported as horizontal but feeble, and the grain as vertical with northwest course. Dike (*a*), 10 to 12 inches thick, dip 65° W., forming west side of quarry, is a fine-grained diabase consisting of soda-lime feldspar (andesine), hornblende from alteration of augite, magnetite, and black mica. Dike (*b*), 18 inches thick, dip 75° SW., forms the north wall. Dike (*c*), 12 inches thick, dip 75° WSW., crosses the center of quarry. Knots measure up to 10 by 7 inches, and rusty stain up to 6 inches on sheet surfaces.

Transportation, by horsepower and an inclined track one-third mile to wharf.

The product goes chiefly into buildings but partly into paving and riprap for breakwater use. Specimens: High School, Charlestown, Mass., entire; Bradford Memorial Chapel, Gloucester, Mass.; Chelsea viaduct over Boston & Maine Railroad at Mystic Wharf, Mass.; Union National Bank, Pittsburgh, Pa.

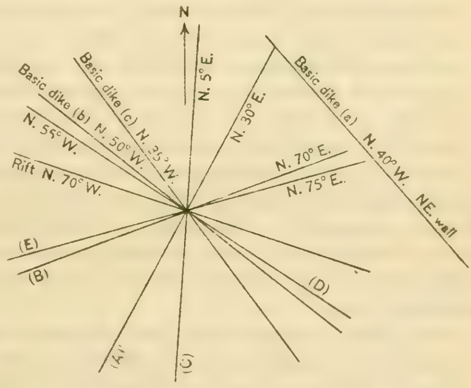

FIGURE 75.—Structure at upper Pigeon Hill quarry, Rockport, Mass.

The **upper Pigeon Hill quarry** is about a mile northwest of Rockport and one-third mile southwest of Pigeon Hill. (See fig. 73.) Operator, Rockport Granite Co., Rockport.

The granite is a hornblende granite of medium-gray, slightly bluish-green color, with inconspicuous black spots. Its texture is medium to coarse and even grained. It is identical in composition with the stone of the lower quarry.

The quarry, opened about 1876, measured in 1906 about 800 feet in a N. 35° E. direction by 450 feet N. 65° W. and from 50 to 100 feet in depth.

Rock structure: The sheets, 4 inches to 12 feet thick, dip mainly west up to 10°. Thin sheets are confined to the upper 20 feet. The sheet structure is generally regular, as shown in Plate XXVII, *A*. Joint and dike courses are given in figure 75. Set (A), vertical, spaced 7 to 50 feet. (B), dip 20° S., spaced 50 feet; its low inclination confuses the sheet structure in places. (C), dip 55° W., spaced 10 to 50 feet. (D), exceptional and intermittent, dip 75° NE. (E), also exceptional, dip 75° SSE. The rift is reported as vertical,

with N. 70° W. course, and the grain as horizontal. There are three or more basic dikes from 12 to 18 inches thick: Dike (*a*) forms the northeast wall; (*b*) about 350 feet from (*a*), dips 80° NE.; (*c*) 300 feet southwest of (*a*), is vertical. The intersection of the sheets by the central dike is well shown in Plate XXVII, *A*. Knots are reported as generally not over 2 feet, but rarely up to 10 by 5 feet. Rusty stain is from 0.5 to 12 inch thick.

Transportation, by inclined track half a mile to wharf.

The product is used largely in construction. Some of it was used in the tower on the southeast corner of the Cambridge and Boston bridge over Charles River.

The **Coalford Swamp quarry** is near Pigeon Cove. Operator, J. Leonard Johnson, Pigeon Cove.

The granite is essentially identical with that of the Pigeon Hill quarries.

The product is rough and hammered granite and paving.

The **Babson Farm quarry** is at the north end of the cape, near Halibut Point, 2½ miles north-northwest of Rockport. (See fig. 73.) Operator, Rockport Granite Co., Rockport.

The granite (specimen D, XXVIII, 25, d) is a hornblende granite of somewhat dark greenish-gray color. It is markedly darker than the granite of the Flat Ledge and Pigeon Hill quarries. Its texture is medium to coarse, even grained, with feldspars up to 0.5 inch and hornblende up to 0.3 inch. Its constituents, in descending order of abundance, are medium greenish-gray potash feldspar (orthoclase), intergrown with soda-lime feldspar and in places much kaolinized; very smoky quartz, with parallel sheets of cavities and abounding in prismatic grayish crystals up to 0.02 millimeter; black hornblende; and very little separate soda-lime feldspar (oligoclase-albite). Accessory: Magnetite, zircon, and apatite. Secondary: Kaolin, limonite, hematite, and chlorite, the last in cracks and isolated particles within the feldspar, also along the boundaries of particles. To the chlorite and the limonite the feldspar owes its greenish tinge.

The quarry, opened about 1897, measures about 350 feet in a northeasterly direction by 150 feet across and from 40 to 50 feet in depth.

Rock structure: Sheet structure is normal. The sheets, 4 inches to 15 feet thick, increasing in thickness downward, are horizontal or dip 10° NW. There are four sets of joints—(a), strike N. 40° E., dip 75° SE. or 90°, spaced 10 to 40 feet, forms the northwest and southeast walls; (b), strike N. 4° W., dip 45°–50° SW., spaced 100 to 200 feet; (c), strike N. 65° W., vertical, forms the northeast and southwest walls; (d), strike N. 80° E., vertical, forms a short heading near the north corner and recurs at rare intervals. The rift is reported as marked and vertical, with N. 50° E. course, and the grain as horizontal. A segregation of uncommon composition, 8 by 4 by 2½ feet, in this quarry is described on page 60. There is some pyrite on the joint faces. Rusty stain is 1 to 6 inches thick along the sheet surfaces.

Transportation, by cart one-fourth mile to wharf, which affords 30 feet of water at low tide.

The **Nickerson quarries** are one-fourth mile southeast of Folly Cove and 2 miles N. 30° W. of Rockport. (See fig. 73.) Operator, W. E. Nickerson, Lanesville. Idle since 1912.

The granite, like specimen D, XXVIII, 29, a, from the Devils Rock quarry, described on page 299, is a hornblende granite of medium-gray slightly buff color and weak contrasts.

The main quarry, opened in 1896, is triangular and measured in 1906 about 350 feet N. 40° W. by 350 feet east and 400 feet N. 40° E. and up to 25 feet in depth. The other opening measured about 100 by 60 feet and 60 feet in depth.

Rock structure: The sheets, 9 inches to 6 feet thick, undulate horizontally. There are four sets of joints—(a), strike nearly east, vertical, spaced 10 to 100 feet; (b), strike N. 40° E., exceptional; (c) in the smaller pit, strike vertical, spaced 10 to 20 feet; (d), in the smaller pit, strike N. 30° W., dip 70° E., spaced from 10 feet up. The rift is reported as vertical, with east-west course, and the grain as horizontal. A vertical diabase dike, 6 feet thick, weathering spheroidally, strikes N. 40° W. and forms the northeast wall of the main quarry. Another east of the quarry has a like course. Knots are reported as not over 1 foot in diameter. Rusty stain is 2 inches thick on lower sheets and 9 inches on the upper ones.

Transportation, by cart one-half mile to Lanesville wharf.

The product consists largely of paving stone, with some "random" stone. The quarry was not operated in 1916.

The **Folly Point Breakwater quarry** is west of Folly Cove, 2½ miles northwest of Rockport. (See fig. 73.) Operator, Coast & Lakes Contracting Corporation, 41 Broad Street, New York. Idle since 1915.

The granite is a gray hornblende granite, which, because of the use to which it was being put, was not specially examined.

The quarry, opened in 1905, measured in 1906 about 250 feet in a west-northwesterly direction by 100 feet across and from 5 to 30 feet in depth.

Sheet structure is scarcely perceptible, but the intersecting joints and headings are so numerous as to facilitate quarrying for the purpose in view.

Transportation, by track 300 feet to wharf.

The product in 1906 was riprap for the Rockport breakwater. The average weight of each block was 4,000 pounds and the minimum 200 pounds.

The **Butman Avenue quarry** is on Butman Avenue, Lanesville. Operator, Cape Ann Granite Corporation, Lanesville.

The quarry was opened in 1906.

The granite is used for buildings, sea walls, bridges, breakwaters, and paving.

The **Devils Rock quarry** is about half a mile southeast of Lanesville and about 1¾ miles N. 58° W. of Rockport. (See fig. 73.) Idle since 1917.

The granite (specimen D, XXVIII, 29, a) is a hornblende granite of general medium gray, not bluish shade and of medium to coarse, even-grained texture, with feldspars up to 0.4 inch and black hornblende up to 0.3 inch. It consists, in descending order of abundance, of light-gray potash feldspar (microcline and orthoclase), from slightly greenish to cream-colored, minutely intergrown with soda-lime feldspar (albite to oligoclase-albite) and somewhat kaolinized; very smoky quartz with cavities; and black hornblende. Accessory: Magnetite, pyrite, zircon, and allanite. Secondary: Kaolin.

The quarry, opened in 1876, measured in 1906 about 400 by 200 feet and averaged about 50 feet in depth.

Rock structure: The sheets, 1 to 18 feet thick, dip 10° N. There are three sets of joints—(a), strike N. 25° E., dip 70° E. to 90°, spaced 3 to 90 feet, forms a heading on the west side; (b), strike N. 70° W., dip 45° to steeply north, spaced from 1 to 50 and 100 feet, forms a heading on the south side and the wall on the north; (c), diagonal, strike N. 25° E., dip about 65° NW., spaced 20 feet at the south end, does not recur. The rift is reported as good, vertical, and with east-west course. There is a 6-inch basic dike on the east side. Gray knots are reported up to 14 by 6 inches. Rusty stain is 1 to 6 inches thick.

Transportation, by cart 1 mile to Lanesville wharf, which affords 13 feet of water at high tide.

The product is used for building and paving. In 1906 this quarry furnished rock for the naval dry dock at Kittery, Maine.

The **Cheves Green Granite quarry** is about 250 feet south of the Devils Rock quarry and 1¾ miles N. 60° W. of Rockport. (See fig. 73.) Quarry idle since 1917.

The granite (specimen D, XXVIII, 30. a), "green granite," is a hornblende granite of somewhat dark olive color, spotted with black, and of medium to coarse, even-grained texture, with feldspars up to 0.5 inch and hornblende up to 0.3 inch. When first quarried the yellowish-green tint is scarcely perceptible, but after a few hours' exposure to rain it becomes marked. Its constituents, in descending order of abundance, are a medium olive-gray potash feldspar (orthoclase and microcline, much of it twinned), minutely intergrown with soda-lime feldspar (many of the feldspars are much kaolinized and contain minute particles, possibly of an oxide of iron); very smoky quartz with cavities and black particles; some separate soda-lime feldspar (albite to oligoclase-albite); and black hornblende. Accessory: Magnetite, allanite (most of it within hornblende particles), and zircon. Secondary: Calcite and limonite stain, some of it proceeding radially from allanite particles, also in cracks and along boundaries of particles.

The contrast in this stone, owing to the dark shade of the quartz, is mostly between the feldspar and the combined quartz and hornblende.

The quarry is somewhat triangular in outline, measuring about 200 feet N. 70° W. by 100 to 200 feet across, and in 1906 was 30 to 90 feet deep.

Rock structure: The sheets are up to 35 feet thick. The joints correspond to sets (a) and (b) of the Devils Rock quarry, and the rift is said to be as in that quarry but less marked.

The **Blood Ledge quarry** is three-fifths mile east-northeast of Bay View and 2 miles N. 62° W. of Rockport. (See fig. 73.) Operator, Rockport Granite Co., Rockport.

The granite (specimens D, XXVIII, 28. b, e), "Rockport sea-green," is a hornblende granite of general somewhat dark olive color, with black spots, and of medium to coarse, even-grained texture, with feldspar up to 0.5 inch and hornblende up to 0.2 inch. Its constituents, in descending order of abundance, are a more or less kaolinized medium olive-gray potash feldspar (orthoclase and microcline, mostly twinned), minutely intergrown with soda-lime feldspar (albite to oligoclase-albite); very smoky quartz with cavities and black particles; black hornblende; and rarely a little biotite. Accessory: Magnetite, allanite, zircon. Secondary: Kaolin, chlorite, limonite stain. This stain occurs in meandering cracks in both feldspar and quartz and along the boundaries of particles, and also radiates from allanite particles, which are one of the primary causes of the yellowish-green tint of the granite. Part of this quarry yields a gray granite like that of the "Deep Pit" (p. 301). The "green granite" described above when first quarried is dark gray, but after wetting becomes in three to four hours olive green. After continued exposure about the quarry the green tint becomes less marked.

An estimate of the mineral percentages in this stone, obtained by the Rosiwal method, with a mesh of 0.7 inch and a total linear length of 16.8 inches, yields the following results: Feldspar, 58.45; quartz, 31.95; hornblende, 9.60.

This stone takes a very high polish and hammers rather light. Some particles of feldspar vary on the polished face from an olive-green to a scarcely greenish milk-white. The contrasts between the three minerals are more marked on the polished face. This granite is well adapted for indoor decorative use.

The quarry, opened about 1868, formed in 1906 an inequilateral quadrangle, the longest side of which measured about 400 feet, and which is bisected by a basic dike and contains an unexcavated central mass upon which the derrick stands, as shown in figure 76. Its depth is about 150 feet below the general surface, from which, however, 50 feet had already been quarried away.

Rock structure: The sheets, 10 to 30 feet thick, dip 15° W. There are four sets of joints, whose courses are given in figure 76—(A), dip 55° E., spaced 3 to 30 feet, forms the west wall; (B), exceptional, dip 50° W.; (C), dip 30° N.; (D), dip 90° or steeply south, forms the short south wall and recurs intersecting the north wall. The rift is reported as vertical, with a N. 85° W. course, and the grain as also vertical and about north-south. The stone is said to split most readily from the ends of the blocks, both along rift and grain. The basic dike, shown in figure 76, is 2 feet thick and dips 70° SW. Dark knots a few inches in diameter were collected, but they are reported as occurring up to the size of half a barrel. Rusty stain is up to 3 inches thick on sheet faces.

Transportation, by a locomotive and track about 1 mile to wharf at Bay View.

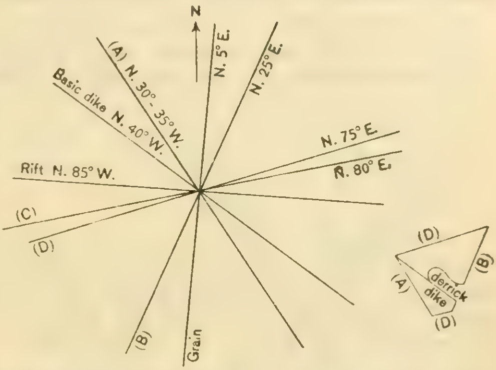

FIGURE 76.—Structure and plan of Blood Ledge quarry, Rockport, Mass.

The product is used for buildings, monuments, docks, and paving. Specimens: Of gray granite, the first story (outside) of Suffolk County courthouse, Boston; six polished columns and two pilasters in the Madison Square Presbyterian Church, New York. Of the polished green granite, Hamilton Club house, Chicago; O. D. Barnes Building, Wichita, Kans.; National State Bank, Newark, N. J.; Woolworth Building, New York. Of the "bush-hammered" green granite, post offices at Elkhart, Ind., and Deadwood, S. Dak.; Syndicate Building, Minneapolis, Minn.; Brooks Bros.' Building, New York.

The "**Deep or Old Pit**" is about one-fifth mile from tidewater at Bay View, on the west side of the cape, 2¼ miles N. 73° W. of Rockport. (See fig. 73.) Operator, Rockport Granite Co., Rockport.

The granite (specimens D, XXVIII, 27, a, b), "Bay View gray," is a hornblende granite of medium-gray shade (lighter than 25, d, Babson quarry, p. 298, and darker than 24, a. 34, a, and 29, a, Flat Ledge, Pigeon Hill, and Cheves quarries, pp. 294, 295, 300), with a slight cream and greenish tinge, spotted with black. Its texture is medium, even grained, with feldspars up to 0.4 inch and hornblende up to 0.3 inch. Its constituents, in descending order of abundance, are a cream-colored and pale-greenish, more or less kaolinized potash feldspar (orthoclase and microcline, mostly twinned), minutely intergrown with soda-line feldspar; very smoky quartz with cavities; a little separate soda-lime feldspar (oligoclase-albite), and black hornblende. Accessory: Magnetite, zircon, and allanite. Secondary: Kaolin, chlorite, calcite, and hematite and limonite stain. The colors of feldspar are evidently due to the chlorite and limonite.

An estimate of the mineral percentages in this granite, by the Rosiwal method, with half-inch mesh and total linear length of 20 inches, yields the following results: Feldspar, 59.60; quartz, 34.70; hornblende, 5.70.

This granite takes a very high polish. In the rough its contrasts are less marked than those of the Flat Ledge and Pigeon Hill stone, and the color of the feldspar is different, but the contrasts are more marked on the polished face, owing to the lighter tinge of the feldspar.

The quarry, opened about 1848, measures about 800 feet N. 20° W., by 500 feet across, but owing to a recess its actual area is about 750 by 500 feet. Its depth is about 200 feet. A diagonal view of this quarry is given in Plate XXVII, *B*, and a rough plan of it in figure 77.

Rock structure: Sheet structure is hardly perceptible but at the south end seems to dip 20° E. and at the northeast corner to undulate horizontally. In the absence of sheets horizontal channeling has to be resorted to. Steeply downward-curving partings, "toenails," are conspicuous in the central part. Joint and dike courses are shown in figure 77.

There are four sets of joints—(A), vertical; (B), dip 60° E.; (C), dip 55° NE; (D), vertical. The rift is reported as vertical, with N. 85° W. course, and the grain as horizontal. The stone is said to split readily from the top. There are five basic dikes. The central one, (a), hornblende diabase of soda-lime feldspar (andesine) micasized, augite, hornblende, magnetite, and black mica (biotite), from 12 to 18 feet thick and dipping 55°–60° NE., crosses the quarry diagonally, but with marked curvature, N. 20°–45° W., and is also faulted along dike (*b*) with a lateral displacement of about 15 feet. Both of these dikes and the fault are shown in Plate XXVI, *B*. Dike (*b*), a lamprophyre consisting of soda-lime feldspar (andesine) altered to white mica, zoisite, and epidote, also with hornblende, augite, and magnetite, is 18 inches thick and dips 55° WNW. Dikes (*c*), (*d*), and (*e*) are vertical. In the northern part a small branching and curved basic dike intersects and branches off from dike (*a*). The relations of these dikes are shown in figure 77. In about the center of the quarry at a depth of 125 feet is an irregular mass of injected hornblende diabase, more fully described on page 54 and also shown in figure 3, which is probably connected more or less remotely with dike (*a*). Rusty stain along sheet surfaces is up to 6 inches thick.

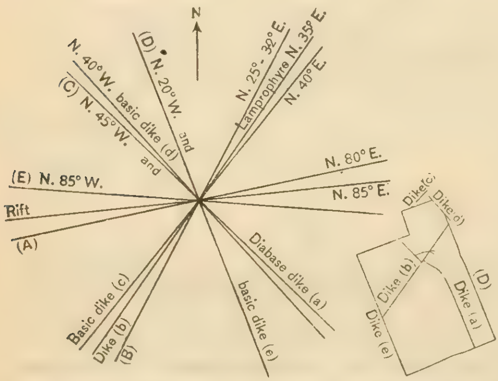

Figure 77.—Structure and plan of Deep Pit quarry, near Bay View, Rockport, Mass.

Transportation, by track half a mile to wharf at Bay View, which affords 15½ feet of water at low tide.

Specimen structures: Boston and Baltimore post offices.

The **Bay View dark-granite prospect** is between the Blood Ledge quarry and the "Deep Pit" near Bay View, and was opened by the Rockport Granite Co., of Rockport. It may be in the small area of augite syenite shown on Sears's geologic map of Essex County.[27]

[27] Sears, J. H., The physical geography, geology, mineralogy, and paleontology of Essex County, Mass. Salem Essex Inst., 1905.

The granite (specimens D, XXVIII, 28½, a, b) is a riebeckite-aegirite-biotite granite of dark brownish-gray color and medium to coarse, even-grained texture, with feldspars up to 0.5 inch in diameter. It consists, in descending order of abundance, of a brownish-gray potash feldspar (orthoclase and microcline), somewhat kaolinized, mostly in twins and minutely intergrown with soda-lime feldspar; slightly smoky quartz; brownish-gray soda-lime feldspar (albite to oligoclase-albite); blue-black riebeckite (soda-hornblende); green-black aegirite (soda-augite); and black mica. Accessory: Magnetite, allanite, zircon, fluorite, and apatite; the first three are somewhat abundant. Secondary calcite is present in small amount, and a little limonite stain occurs to which the feldspars owe their brownish tinge. They also contain minute particles of all the black silicates.

This rock takes a very high polish and hammers rather light. The quartz and feldspar being of about one shade, the only contrast on the polished face is between these and the black silicates. On the rough face the contrast is slight.

The **Pigeon Cove porphyry quarry** is on a dike of altered diabase porphyry, 18 feet wide, represented by Shaler [28] and Tarr as exposed for half a mile on the hillock west of Pigeon Cove, with a N. 21° W. course, also as reappearing in Rockport three-fourths mile west of Gap Head with a N. 9° W. course. Washington [29] refers to this dike as cutting the quarry pit at Pigeon Cove and describes it microscopically as a labradorite porphyry. Operators, Fuller, Foley & Co., West Quincy, Mass.

This diabase porphyry (specimens D, XXIX, 89, a, b), "Rockport porphyry," has a very dark green or black fine-grained groundmass, with porphyritic feldspars of medium greenish-gray color, from 0.2 to 4.42 inches in length by about 0.78 inch in width. Many of the crystals are from 1 to 2 inches long. Their striation shows plainly. Plate XXV, *B*, shows the general character of the rock. The groundmass consists of these minerals, in descending order of abundance: Lime-soda feldspar (andesine-labradorite), partly micacized; augite, largely altered to a green hornblende; and chlorite, biotite (black mica), magnetite, apatite, and rarely a little secondary calcite.

This rock takes a very high polish, and the contrast between the black groundmass and the large pale-greenish crystals is most striking.

Product specimens: Four polished disks, 5 inches thick and 2 feet 6 inches in diameter (made in two halves), embedded in the Roman pavement about the Bethesda Fountain, also a band around its central drain plate, on "The Terrace" at end of "The Mall" in Central Park, New York. The texture of this porphyry is shown in Plate XXV, *B*.

HAMPDEN COUNTY.

MONSON.

According to Emerson,[30] the gneiss of Monson forms a narrow north-south strip which, with a short interruption, extends from the New Hampshire border to the Connecticut border. It is called Monson granodiorite and is regarded as of late Carboniferous or post-Carboniferous age. The parallel banding of the rock is attributed to segregation of the biotite during flowage.

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[28] Shaler, N. S., The geology of Cape Ann, Mass.: U. S. Geol. Survey Ninth Ann. Rept., p. 609, pl. 77, 1889.

[29] Washington, H. S., The petrographical province of Essex County, Mass.: Jour. Geology, vol. 7, p. 290, 1899.

[30] Emerson, B. K., Geology of Massachusetts and Rhode Island: U. S. Geol. Survey Bull. 597, p. 241, pl. 10, 1917.

The **Flynt quarries** are in Monson Township on the southwest side of Bunyan Mountain, 1¼ miles north-northwest of Monson station. (See Palmer topographic map, U. S. Geol. Survey, and Plate XXIII.) Operator, William N. Flynt Granite Co., Monson.

The granite (specimens D, XXX, 90, a, b, c), Monson (darker variety, used for faces of buildings), is a quartz-mica diorite gneiss (granodiorite) of dark to very dark gray shade and fine to very fine elongated (unplicated) gneissose texture, with feldspars and mica up to 0.2 inch but mostly under 0.1 inch. Its constituents, in descending order of abundance, are clear colorless quartz with cavities; bluish translucent to milk-white soda-lime feldspar[31]; and biotite (black mica). Accessory: Magnetite (fourth in order of abundance), garnet, zircon, apatite, and allanite. Secondary: Epidote (fifth in order of abundance) and chlorite. No effervescence with muriatic-acid test. No pyrite on the polished face.

A light to medium gray variety (specimen 90, c) with fine bands of dark gray has the same composition as the rock described above but less biotite. This stock is used for curbing, foundations, etc.

The following analysis of it was made by W. F. Hillebrand[32]:

Analysis of quartz-mica diorite from Flynt quarry, Monson, Mass.

Silica (SiO_2)	65.02
Alumina (Al_2O_3)	18.37
Iron sesquioxide (Fe_2O_3)	1.21
Iron oxide (FeO)	2.06
Magnesia (MgO)	1.49
Lime (CaO)	6.20
Soda (Na_2O)	3.96
Potash (K_2O)	.64
Water (H_2O at 105°)	.09
Combined water (H_2O above 105°)	.42
Titanium dioxide (TiO_2)	.33
Carbon dioxide (CO_2)	None.
Phosphoric acid (P_2O_5)	.14
Manganese oxide (MnO)	.09
Barium oxide (BaO)	Trace.
	100.92

Merrill[33] states that a test of this gneiss showed a crushing strength of 15,390 pounds to the square inch with the pressure applied at right angles to the foliation, and 12,720 pounds with the pressure applied in the direction of the foliation.

The fine and even foliation of this gneiss renders it more suitable for some purposes and less for others than a true granite. The absence of pyrite in its composition is in its favor as a building stone. Its foliation prevents its taking a high polish.

The first opening was made in 1824 by United States agents for the construction of the armory at Springfield, Mass. The quarry in operation in 1910 was about 350 by 150 feet and from 20 to 30 feet deep.

[31] In describing thin sections of this rock in U. S. Geol. Survey Bull. 470, the writer mistook the grating twinning of plagioclase for microcline and so determined the rock as a biotite-quartz monzonite.

[32] U. S. Geol. Survey Bull. 419, p. 22, analysis 1, 1910.

[33] Merrill, G. P., Stones for building and decoration, p. 406, New York, 1891.

Rock structure: The sheets, 6 inches to 10 feet thick, mostly 2 to 5 feet, dip 5°–20° W. The only joints are parallel to the foliation and are spaced 10, 50, and 90 feet. The gneiss foliation strikes N. 10° E. and dips 75° N. 80° W. The rock is of light, medium, and dark gray colors in alternating bands of very different widths. Some are not over 0.25 inch wide; others 2 or 3 feet. These bands are free from plications, but one was found doubled over on itself vertically for the space of a foot. Each band as seen on the sheet surface also varies greatly in width. Some foliation faces are chloritic. The rift corresponds to the foliation and the grain is horizontal. A few pegmatite bands up to 3 inches thick occur. There is no rusty stain.

The Monson quarries have long been referred to as affording evidence of compressive strain,[84] but although the rock is still under a north-south strain, fracturing attended with explosive sounds no longer occurs.

Transportation, by 1¼- mile siding from Central Vermont Railway at Munson.

The product is used for buildings, bridges, and monuments; the seconds for curbing, foundations, and crushed stone for concrete. Specimens: Horatio Lyon Library, Monson; Walker Hall, Amherst College, Mass.; Church of St. Francis Xavier on Sixteenth Street, Isabella Home on One hundred and nineteenth Street, Munn Monument, Woodlawn Cemetery, New York; Roman Catholic Church and rectory, West New Rochelle, N. Y.; residence of Charles La Dow, Thurlow Terrace, Albany, N. Y.; Congregational Church and Doane buildings, Rockville, Conn.; fountain at Weatogue, Conn.; Hall Memorial Chapel, Watertown, Conn.; high school, East Orange, N. J.; Park Avenue Methodist Church, Chicago.

HAMPSHIRE COUNTY.

PELHAM.

The granite at Pelham is in a lenticular area designated on the map of Bulletin 597 "Pelham granite (gray biotitic gneissoid granite)" and shown as extending from Northfield to Belchertown with a maximum width of 8 miles. Its age is regarded by Emerson as late Carboniferous or post-Carboniferous, and its banding is attributed to segregation in flowage.

The **Ward quarry** is in Pelham Township, 2 miles northeast of West Pelham and about 4 miles east-northeast of Amherst. (See Belchertown topographic map, U. S. Geol. Survey, and Pl. XXIII.) Operator, E. P. Bartlett, Amherst. Idle since 1908.

The granite (specimens D, XXX, 91, a, b, c), Pelham, is a biotite granite gneiss of general dark bluish-gray color and very fine elongated (unplicated) gneissic texture, with feldspars and mica under 0.1 inch. It is finely banded, the bands being mostly not over 0.04 inch wide and of very dark gray alternating with white. There are fine-grained white bands without black mica (specimen c). There are also lenses of quartz and feldspar up to 0.3 inch wide and several inches long, containing black mica crystals up to 0.3 inch in diameter, lying transverse to the foliation (specimen b). Its constituents, in descending order of abundance, are clear to translucent bluish potash feldspar (microcline and orthoclase); very pale smoky quartz; biotite (black mica) with a little muscovite; and very little milk-white plagioclase feldspar, kaolinized. Accessory: Magnetite, titanite, zircon, allanite, apatite. Secondary: Kaolin, epidote, carbonate, chlorite. No effervescence with muriatic-acid test.[85]

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[84] See Niles, W. H., Some interesting phenomena observed in quarrying: Boston Soc. Nat. Hist. Proc., vol. 14, pp. 80–87, 1872; vol. 16, pp. 41–43, 1874; also Emerson, B. K., Geology of Old Hampshire County, Mass.: U. S. Geol. Survey Mon. 29, pp. 64–65, 1898.

[85] Emerson's description of the stone will be found on pp. 248–249 of Bulletin 597.

An analysis of this gneiss made by George Steiger, a chemist of this Survey, follows:

Analysis of biotite granite gneiss from Pelham, Mass.[56]

Silica (SiO_2)	72.45
Alumina (Al_2O_3)	13.32
Iron sesquioxide (Fe_2O_3)	1.93
Iron oxide (FeO)	.63
Magnesia (MgO)	.44
Lime (CaO)	1.81
Soda (Na_2O)	3.55
Potash (K_2O)	3.86
Water (H_2O at 105°)	.59
Combined water (H_2O above 105°)	1.51
Titanium dioxide (TiO_2)	.27
Phosphoric acid (P_2O_5)	.06
	100.42

In comparing this analysis with that of the Monson granodiorite (p. 304) it will be noticed that this has higher percentages of silica and potash and lower of alumina. iron oxides, magnesia, and lime. The microscopic descriptions of the two rocks show that the Monson granodiorite contains much more soda-lime feldspar than the Pelham stone.

The Pelham granite resembles that of Monson in appearance, and its economic uses and value are similar. The shade of the Pelham stone is a trifle lighter than that of the best dark granite of the Monson quarry.

The quarry, opened before 1862 and now worked irregularly, measures about 200 feet in a northwest direction and has a working face 25 feet high on the northeast.

Rock structure: The sheets, 6 inches to 2 feet thick, are parallel to the gneiss foliation, which strikes N. 80° W. and dips in undulations 5°–13° N. 10° E. The sheet surfaces are slickensided, with striae striking N. 10° E. There are no joints. The rift is parallel to the foliation, and the grain is probably vertical, with N. 10° E. course. Pegmatite dikes of light feldspar, smoky quartz, and biotite up to an inch thick dip 50°–60° about north. Lenses of smoky quartz, up to 30 feet long and to 6 inches thick, lie in the foliation, and porphyritic feldspar lenses up to 3 by 2 inches are strung along in the foliation, forming in places, with biotite and quartz, pegmatitic bands up to 2 inches thick. One such lens contains black hornblende masses 2 inches by 1 inch.

Transportation, by cart about 4 miles to Amherst.

The product is used for local buildings. Specimens: Old gymnasium and basement story of geological and zoological building at Amherst College.

MIDDLESEX COUNTY.

GEOLOGIC RELATIONS.

The quarries in Acton are in an area designated on the map of Bulletin 597 "igneous gneiss of undetermined age (including schist)." Those in Groton and Westford are in an area designated "Ayer granite (coarse porphyritic biotite muscovite granite)" and are regarded by Emerson[56a] as of a late Carboniferous or post-Carboniferous age. The quarry in Townsend is in an area designated

[56] U. S. Geol. Survey Bull. 419, p. 22, analysis L, 1910.

[56a] U. S. Geol. Survey Bull. 587, pp. 218, 223–225.

"Fitchburg granite (white muscovite-biotite granite)," a description that hardly fits the granite quarried in Townsend and also across the State line in Brookline, N. H., which is clearly quartz monzonite.[37] However, these may be intrusives in the "Fitchburg granite."

ACTON.

The **Harris quarry** is in Acton Township, half a mile north-northwest of North Acton station. (See Lowell topographic map, U. S. Geol. Survey and Pl. XXIII.) Operator, North Acton Quarry Co., North Acton.

The granite (specimens D, XXX, 111, a, b), "Acton," is a biotite muscovite-quartz monzonite gneiss of light bluish-gray color and of fine gneissic texture, with feldspars under 0.2 inch, exceptionally up to 0.3 inch, and mica up to 0.1 inch. Its constituents, in descending order of abundance, are milk-white soda-lime feldspar (oligoclase), some of it much kaolinized, some minutely intergrown with quartz (vermicular structure); in nearly equal amount, clear to translucent bluish potash feldspar (microcline and probably orthoclase); clear colorless quartz, strained, with rutile needles and some cavities; biotite (black mica), some of it chloritized; and muscovite (white mica). Accessory: Magnetite, rather plentiful, apatite, rutile, zircon. Secondary: Kaolin, epidote, carbonate, chlorite. It effervesces with muriatic acid test.

This is a bright stone of sufficient coarseness to show the mineral contrasts, the colors being black and white.

The quarry, opened in 1885, measured in 1910 200 by 100 feet and from 10 to 35 feet deep.

Rock structure: There are traces of sheets from 6 inches to 3 feet thick, but blocks 12 feet thick can be obtained. This is a "boulder quarry." There are two sets of joints—(*a*), strike N. 75° E., dip 75° S. 15° E., slickensided and coated with epidote, one only, forming the north wall; (*b*), strike N. 35° W., dip 45° S. 55° W. to 90°, spaced 5 to 50 feet. The rift is about horizontal, and the grain vertical, with N. 55° E. course. Pegmatite dikes up to 5 inches thick have a N. 30° W. course. Rusty stain is up to a foot thick on the outer masses.

Transportation, by cart to North Acton station, half a mile.

The product is used for buildings, monuments, and curbing. Specimens: James Wetherbee monument, Woodlawn Cemetery, Acton; Samuel Guilford monument, Mount Hope Cemetery; and Dunlop monument, Sleepy Hollow Cemetery, West Acton.

Quarry not operated in 1916.

The **McCarthy quarry** is in Acton Township, about half a mile northwest of North Acton station, at the top of a small knoll. (See Lowell topographic map, U. S. Geol. Survey, and Pl. XXIII.) Operator, Thomas McCarthy, North Acton. Idle since 1916.

The granite (specimen D, XXX, 112, a), "Acton fine," is a biotite-muscovite-quartz monzonite of light to medium bluish-gray color and of fine to very fine, obscurely gneissoid texture, with feldspars under 0.2 inch and mica up to 0.1 inch, but mostly under 0.05 inch. Its constituents, in descending order of abundance, are translucent to milk-white soda-lime feldspar (oligoclase-andesine), slightly kaolinized; in nearly equal amount, clear bluish potash feldspar (microcline and probably orthoclase); clear colorless quartz, strained, in places granulated and with cavities; biotite (black mica); and muscovite (white mica), also stringers of secondary fibrous muscovite. Accessory: Magnetite,

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[37] Idem, pp. 232, 233.

apatite, and zircon. Secondary: Epidote, carbonate, muscovite, and kaolin. No effervescence with muriatic-acid test.

This is a fine-grained stone without mineral contrasts and is suitable for fine work.

The quarry, opened in 1890, measured in 1910 150 by 80 feet and 20 feet deep.

Rock structure: The sheets, 6 to 16 inches thick, are horizontal or dip 10° NE. There are no joints. The rift is horizontal, and the grain vertical, with northeast course. A pegmatite dike 2 feet thick is parallel to the grain. On the southeast, northwest, and southwest sides the granite is in contact with a quartz-mica diorite. On the northwest side, 6 feet from the contact, there is an inclusion of this diorite gneiss. There is no rusty stain.

Transportation, by cart about three-fourths of a mile to North Acton station.

The product is used for buildings, monuments, and curbing. Specimens: Schoolhouse back of a mill on Maynard estate, Maynard.

GROTON.

The **Rafferty quarry** is in Groton Township, 4 miles east-southeast of Groton village and 1½ miles northwest of West Graniteville station. (See Groton and Lowell topographic maps, U. S. Geol. Survey, and Pl. XXIII.) Operator, Groton Granite Co., 10 Faneuil Hall Square, Boston. Idle in 1920.

The granite (specimens D. XXX, 100, c, d), "Groton," is a muscovite-biotite granite gneiss of light to medium gray shade and of medium, inclining to coarse gneissic, slightly porphyritic texture, with feldspars up to 0.5 inch and mica up to 0.1 inch. Its constituents appear to be identical with those of specimens 93, a, b, c, from the H. E. Fletcher quarry on Oak Hill, in Westford (p. 309). It effervesces with muriatic-acid test.

This stone, like the granite gneisses of Westford, is devoid of mineral contrasts. It is well adapted for base courses and all work requiring much greater transverse strength in one direction than in the other and for curbing.

The quarry, begun in a small way in 1860, but reopened in 1910, was then 50 feet square, and its west side was 30 feet higher than the east side.

Rock structure: The sheets, 2 to 6 feet thick, dip 20° N. 35° E. One steep joint at the west side strikes N. 75° E. The gneiss foliation is vertical, with N. 30° E. strike. The rift is horizontal, and the grain corresponds to the foliation, the face of which is more micaceous than the rift face. There is a 30-foot inclusion of porphyritic biotite granite gneiss (described on p. 63), also two smaller ones. A pegmatite dike up to 6 inches thick crosses the gneiss and the inclusion, as do also small dikes of aplite gneiss with oligoclase-albite. No stain below the surface sheet.

Transportation, by cart 1½ miles to siding near West Graniteville station.

The **Shaker quarry** is in Groton Township, on an 80-foot hillock three-fourths mile north-northwest of Littleton station and 4 miles southeast of Groton village. (See Groton topographic map, U. S. Geol. Survey.) Operator, H. N. Fletcher, Graniteville.

The granite (specimen D, XXX, 106, a.), "Groton," is a muscovite-biotite granite gneiss of medium bluish-gray color and slightly porphyritic, medium, inclining to fine gneissic texture, with feldspars up to 0.3 inch. Its constituents, in descending order of abundance, are translucent bluish potash feludspar (microcline and orthoclase); light smoky quartz with rutile needles and cavities, granulated, with particles under 0.37 millimeter; milk-white soda-lime feldspar (near oligoclase-albite), kaolinized and micacized; muscovite (white mica), and biotite (black mica), some of it chloritized. There are also some fibrous muscovite stringers. Accessory: Garnet, apatite. Sec-

ondary: Kaolin, two white micas, epidote, chlorite. No effervescence with muriatic acid test.

This stone is like the other gneisses of Groton and Westford but more bluish and of uniform color, without mineral contrasts.

The quarry in 1910 was of triangular form, 100 feet on a side and 10 to 25 feet deep.

The sheets, 6 inches to 3 feet thick, undulate.

The product has been used for buildings.

WESTFORD.

The active quarries of Westford are in two groups. One is on Oak Hill, an irregular mass of knolls rising to a height of 200 feet above Merrimack River, in the northern part of the township. All but one of this group have their granite landings at Woods Corners (Slab City), on both Merrimack River and a siding of the Boston & Maine Railroad, 4 miles roughly west of Lowell. The other group is on Snake Meadow Hill, 100 to 160 feet above the nearest railroad, in the southwestern part of the township. This group has its outlet at the Graniteville and West Graniteville stations, not a mile away and about 9 miles west-southwest of Lowell. (See Pl. XXIII.)

The **H. E. Fletcher quarry** is on the southeastern part of Oak Hill, in Westford Township, 1¼ miles northwest of West Chelmsford station. (See Lowell topographic map, U. S. Geol. Survey.) Operator, H. E. Fletcher Co., West Chelmsford.

The granite (specimens D, XXX, 93, a, b, c), "Oak Hill," is a muscovite-biotite granite gneiss of very light, slightly bluish-gray color on the rift face but light gray on the grain face, and of medium gneissic, slightly porphyritic texture, with feldspars up to 0.3 inch and micas up to 0.2 inch. Its constituents, in descending order of abundance, are translucent bluish potash feldspar (microcline and orthoclase), slightly kaolinized; milk-white soda-lime feldspar, (oligoclase), much kaolinized and with some white mica; clear colorless quartz, finely granulated, with particles to 0.5 millimeter but mostly under 0.37 millimeter, and with rutile needles and some cavities; muscovite (white mica); biotite (black mica), some of it chloritized; and stringers of fibrous muscovite. Accessory: Apatite. Secondary: Kaolin, white mica, carbonate, epidote, chlorite. Very slight effervescence with muriatic-acid test.

This gneiss is very well adapted for base courses and all work requiring much greater transverse strength in one direction than in another. It is devoid of mineral contrasts. The absence or greater scarcity of pyrite and magnetite is favorable to the durability of its color.

The quarry, opened about 1880, measured in 1910 about 700 feet in a northeast direction by 500 feet across and from 30 to 40 feet in depth. Since then its area has been extended without increasing its depth.

Rock structure: The sheets, 8 inches to 12 feet thick, undulate horizontally. There are three sets of joints—(a) strike N. 30°–40° E., curving to N. 55° E., dip 70° N. 55° W. to 90°, and forms a heading on the southeast wall; (b) strike N. 30° W., dip 60° N. 60° E., on southwest wall; (c) strike N. 50° E., dip 65° N. 40° W., spaced 300 feet and over. The gneiss foliation strikes N. 30°–40° E. and dips 65° N. 55° W. but appears to be crossed by a shear zone dipping 65° about southeast. The relations of the foliations are obscure. The rift is horizontal, and the grain vertical, with N. 40° E. course, parallel to the foliation, which shows more mica than the rift face. An aplite dike, 1½ inches thick, bordered with half an inch of pegmatite on either side, has an east-west course. Pegmatite dikes are up to 8 inches thick. Where the granite is

pegmatitic the mica is in crystals up to 0.4 inches across. (Specimen D, XXX, 93, c.) The amount of limonite stain is insignificant. Mr. Fletcher finds a compressive strain which relieves itself by an expansion amounting to an inch in 100 feet.

The fine stock produced is used for buildings, and the coarse pegmatitic rock for bridges, paving, curbing; the waste is crushed for concrete. Specimens: East and west wings of Massachusetts Capitol; First National Bank, Boston: granite for the Frick Mansion at Prides Crossing, near Beverly; base course and steps of courthouse, Lowell, Mass.; soldiers' monument, Plaistow, N. H.; 20 stories (sixth to twenty-fifth) of Bankers' Trust Co. Building, Wall and Nassau streets, New York; steps, base course, and approaches of post office and United States courthouse, New Orleans.

The **Merrill quarry** is near the north end of Oak Hill, in Westford Township, 6 miles west of Lowell. (See Lowell topographic map, U. S. Geol. Survey.) This quarry was operated in 1910 by F. A. Mallory but is now disused.

The granite, "Oak Hill," is a muscovite-biotite granite gneiss of very light gray shade and of medium gneissic, slightly porphyritic texture identical with that of the H. E. Fletcher quarry, described on page 309.

The quarry, opened about 1830, measured in 1910 700 to 1,000 feet in a northeasterly direction by 500 feet across and 40 feet deep.

Rock structure: The sheets, 6 inches to 8 feet thick, dip 10° NE. but are intersected on the east wall by exceptional secondary sheets 10 to 20 feet thick, dipping 20° N. 47° E. (See p. 36.) There is but one set of joints, striking N. 75° E. and spaced on the average 50 feet. The gneiss foliation strikes N. 40° E. The rift is horizontal, and the grain vertical, with N. 35° E. course. The stone splits better along the foliation than along the grain. There are dikes of pegmatite and aplite with black tourmaline. The aplite, consisting of potash feldspars, quartz with rutile and cavities, oligoclase-albite, apatite needles, carbonate, and epidote, but no mica, has bands of black tourmaline 0.4 inch apart and 0.2 inch wide. An inclusion, 2 by 18 inches, of fine banded biotite gneiss was noticed.

Transportation, by cart about 2 miles to Woods Corners siding.

The product was used mostly for curbing and paving.

The **Peterson quarry** is on Oak Hill, in Westford Township, a little over half a mile about north-northwest of the H. E. Fletcher quarry. Operator, Peterson Bros., West Chelmsford.

The granite (specimens D, XXX, 94, a, b) is similar to that of the H. E. Fletcher quarry, described on page 309, but a little coarser.

The quarry, opened in 1899, was in 1910 200 feet square and 15 to 30 feet deep.

Rock structure: The sheets, 8 inches to 6 feet thick, dip 5°–10° SE. There are two sets of joints—(a), strike N. 15°–30° E., dip steep to 90°, spaced 10 to 75 feet; (b), strike N. 65° W., dip 60° S. 25° W., also N. 25° E. The gneiss foliation strikes N. 40° E. and dips 70° S. 50° E. The rift is horizontal, and the grain vertical, with N. 27° E. course. Pegmatite dikes up to a foot thick have a N. 60° W. course. Rusty stain up to 6 inches thick is confined mostly to the thin sheets. There is a compressive strain in the grain direction.

Transportation, by cart 3 miles to Woods Corners siding.

The product is used for trimmings, steps, sills, and curbing. Specimens: Trimmings on Massachusetts Mills, East Merrimac Street, Lowell.

The **Perley Carkin quarry** adjoins the Peterson quarry on the northeast. Operator, Perley A. Carkin, North Chelmsford.

The granite is identical with that of the Peterson quarry.

The quarry, opened in 1905, was in 1910 400 by 200 feet and 15 to 34 feet deep.

Rock structure: The sheets, 1 foot to 8 feet 4 inches thick, are about horizontal. The only joints strike N. 15°–30° E., are vertical or steep, and are spaced 30 to 140 feet. Foliation, rift, and grain are the same as in the Peterson quarry. The amount of stain is small.

Transportation, by cart 1¾ miles to Woods Corners siding.

The product is used for curbing, paving, and trimming.

The **C. W. Carkin quarry** is nearly a quarter of a mile east of the Perley Carkin quarry. Operator, C. W. Carkin, North Chelmsford.

The granite is identical with that of the Peterson quarry.

The quarry was in 1910 200 by 60 feet and 10 to 15 feet deep.

Rock structure: The sheets, 6 inches to 4 feet thick, are horizontal. Two joints, one on either side of the quarry, strike N. 30° E. Foliation, rift, and grain are the same as in the Peterson quarry.

The product is used for curbing, paving, and trimming.

The **Cartwright quarry** is on Oak Hill, in Westford Township, about a mile north-northwest of the H. E. Fletcher quarry and nearly half a mile southeast of the Merrill quarry. Operator, George A. Morris, North Chelmsford.

The granite is identical with that of the quarries above mentioned.

In 1910 the quarry was 50 feet square and 5 to 10 feet deep. The sheets are 5 to 10 feet thick.

The product is used for curbing.

The **H. N. Fletcher quarries** are on the top and south side of Snake Meadow Hill, in Westford Township, about half a mile north-northwest of Graniteville station. See Lowell topographic map, U. S. Geol. Survey, and Pl. XXIII.) Operator, H. N. Fletcher, Graniteville.

The granite (specimen D, XXX, 101, a), "Graniteville," is a muscovite-biotite-quartz monzonite gneiss of very light gray shade and of gneissic, medium, inclining to fine, slightly porphyritic texture, with feldspars up to 0.3 inch but mostly not over 0.2 inch and micas up to 0.2 inch. Its constituents, in descending order of abundance, are milk-white soda-lime feldspar (oligoclase-albite), generally kaolinized and micacized, some with bent laminae; clear colorless quartz, granulated, with particles mostly not over 0.25 millimeter, and with rutile needles; translucent bluish potash feldspar (microcline and orthoclase); muscovite (white mica) and stringers of fibrous muscovite; and biotite (black mica), some of it chloritized. Accessory: Garnet. Secondary: Kaolin, white micas, epidote, carbonate. The quartz forms a matrix of fine particles in which the feldspars lie. Some effervescence with muriatic-acid test.

The gneiss in places is coarsely porphyritic (specimen D, XXX, 101, b), of medium-gray color with dark bluish-gray feldspars up to an inch square and even 2 inches by 0.75 inch. The matrix has feldspars up to 0.2 inch and micas up to 0.1 inch. The feldspars are microperthite—potash feldspar (microcline), minutely intergrown with soda-lime feldspar (oligoclase-albite).

Some of the foliation faces of the gneiss carry muscovite crystals (specimen D, XXX, 102, a).

The stone of these quarries is generally lighter than that of the Oak Hill quarries but possesses the same general character and qualities.

The north quarry, opened in 1906, was in 1910 250 feet square but had an unexcavated part 50 by 125 feet on one side.

Rock structure: The sheets, 1 to 6 feet thick, undulate horizontally. There are five sets of joints—(*a*), strike N. 70° E., dip 45° S. 20° E., spaced 20 feet; (*b*), strike N. 10° W., forms a heading 70 feet wide beyond the east wall; (*c*), strike N. 20° W., dip steep to 90°, spaced 8 feet; (*d*), vertical, strike N. 10° E.; (*e*), strike N. 30°–40° E., dip 70° N. 55° W. to 90°, spaced 50 feet and over, forms the east wall. The rift is horizontal and

the grain vertical, with N. 30° E. course. The foliation is plicated, with a strike of N. 40° E. Pegmatite lenses occur.

The south quarry, opened in 1860, was in 1910 200 by 150 feet and 10 to 40 feet deep. The sheets, rift, and grain are the same as in the north quarry. There are two sets of joints—(*a*), vertical, strike N. 35° E., spaced 4 to 10 feet; (*b*), vertical, strike N. 75° W., spaced 3 to 6 feet.

Transportation, by cart half a mile to Graniteville station.

The product is used mostly in curbing and paving.

The **Palmer quarries** are on the north side of Snake Meadow Hill, in Westford Township. (See topographic map, U. S. Geol. Survey, Lowell.) Operators, Lewis P. Palmer & Sons, Graniteville.

The granite of the upper quarry (specimens D, XXX, 92, b, c), "Graniteville," is a medium-gray quartz monzonite of gneissic, slightly porphyritic, medium inclining to fine texture, with feldspar up to 0.3 inch and micas up to 0.2 inch, rarely 0.3 inch. The stone of the lower quarry is reported as a little coarser than this. The constituents, in descending order of abundance, are grayish soda-lime feldspar, kaolinized and micacized; in about equal amount, bluish-gray potash feldspar (microcline and orthoclase), intergrown with quartz that is circular in cross section; light smoky quartz, finely granulated, with particles up to 0.25 (rarely 0.37) millimeter, and with rutile needles and cavities; muscovite (white mica), some with prism faces, also fibrous muscovite stringers; and biotite (black mica), some of it chloritized. Accessory: Magnetite, apatite. Secondary: Epidote, carbonate, kaolin, white micas. It effervesces slightly with muriatic-acid test.

This stone structurally resembles that of the Oak Hill quarries, but its color is a little darker and its mineral composition slightly different. It is much darker than the gneiss of the H. N. Fletcher quarry.

The upper quarry was in 1910 about 300 by 215 feet and 20 to 40 feet deep. The lower quarry, 600 feet east of the upper, was about 200 by 100 feet and 15 feet deep.

Rock structure: The sheets in the upper quarry are 1 to 5 feet thick and dip 10° about northeast; in the lower quarry they are 2 to 7 feet thick and about horizontal. There are four sets of joints—(*a*), strike N. 20° E., dip 75° N. 70° W., forms the west walls; (*b*), vertical, strike N. 35° W., spaced 50 feet; (*c*), strike about east, dip 70° N. to 90°, forms the north and south walls; (*d*), vertical, strike N. 10° W., forms a 20-foot heading. The gneiss foliation strikes N. 45°–60° E. and dips 75° SSE. to 90°. The rift is horizontal, and the grain vertical, with northeast course like the foliation. The grain face is thus more micaceous than the rift face. There is a 12-inch dike of alternating bands of aplite and pegmatite with a N. 20° E. course A fine-grained inclusion of biotite schist or gneiss with zoisite from this quarry has been described on page 63. Rusty stain is up to 3 inches thick on sheet surfaces.

Transportation, by cart three-fourths mile to Graniteville station.

The product is used for building, curbing, and paving.

The **Couture quarry** lies on the west side of Snake Meadow Hill, in Westford Township. It is now idle.

The granite is like that of the Palmer quarries, described above.

The quarry, opened in 1906, was, in 1910, 150 by 100 feet and 12 feet deep.

Rock structure: The sheets, 2 to 12 feet thick, are horizontal. There are three sets of joints—(*a*), vertical, strike N. 10° W., spaced 3 to 12 feet; (*b*), strike N. 30° E., dip 70° S. 60° E., and also N. 60° W.; (*c*), strike N. 80° E., spaced 10 to 20 feet, coated with epidote and quartz crystals and slickensided,

crosses the quarry lengthwise in the center. Rift, grain, and foliation are as in the other quarries of this hill.

Transportation, by cart about three-fourths mile to Graniteville station.

The product is used for curbing.

The **Wright quarry** is on the east side of Snake Meadow Hill, in Westford Township. Operator, Charles E. Couture, Graniteville.

The granite is the same as that of the Palmer quarries (p. 312).

The quarry, opened in 1880, was in 1910 300 by 150 feet and 15 to 20 feet deep.

Rock structure: The sheets, 6 inches to 3 feet thick, are horizontal. There are three sets of joints—(*a*), vertical, strike N. 10° W., forms a heading on the east wall; (*b*), strike N. 10° E., one near west wall, one in center, and possibly others concealed by waste; (*c*), steep, strike N. 45° E., forms the west wall. The gneiss foliation strikes N. 50° E. Pegmatite and aplite dikes up to a foot thick have northerly courses.

The product is used for curbing.

The **Hildreth quarry** lies south of the Couture quarry, on the west side of the hill, in Westford Township. Operator, H. V. Hildreth, Westford. Idle in 1922.

The granite is like that of the Palmer quarries (p. 312).

The quarry, opened about 1845, was in 1910 300 by 150 feet and 10 to 40 feet deep.

Rock structure: The sheets, 1 to 13 feet thick, dip at a low angle to the north. There are two sets of joints—(*a*), vertical or steep, strike N. 10° E., spaced 150 feet, forms east and west walls; (*b*), discontinuous, strike N. 50° E., dip 60° N. 40° W., spaced 2 to 10 feet, forms a heading on the east wall. Rift, grain, and foliation are as at the other quarries of this hill. Rusty stain is up to 4 inches thick on sheet surfaces.

The product is used for building and curbing.

Other quarries on Oak Hill in Westford are the **Prescott quarry**, operator, Arthur Decarteret, of Tyngsboro; and the **Barker Lot quarry**, operator, Thomas Le Masurier, of North Chelmsford.

TOWNSEND.

The **Barker Hill quarry** is on the southwest side of Barker Hill, about 200 feet above the railroad, in Townsend Township, 1½ miles north-northwest of West Townsend station and about 1¼ miles north of West Townsend village. (See Groton topographic map ,U. S. Geol. Survey, and Pl. XXIII.) Operator, Duncan Rusk, West Townsend.

The granite (specimen D, XXX, 113, b), "West Townsend white," is a biotite-quartz monzonite of very light, faintly buff-gray color and of even-grained medium inclining to fine texture, with feldspars under 0.3 inch, rarely over 0.4 inch, and mica up to 0.1 inch. Its constituents, in descending order of abundance, are colorless clear to translucent potash feldspar (microcline), much kaolinized and intergrown with quartz that is circular in cross section; in nearly equal amount, milk-white to faint pinkish soda-lime feldspar (oligoclase-albite), somewhat micacized; light smoky quartz with cavities in sheets; biotite (black mica); and a little muscovite or bleached biotite. Accessory: Magnetite (plentiful), apatite, zircon, and rutile(?) needles in chlorite. Secondary: Chlorite after biotite, carbonate, a white mica, and hematite stain from the magnetite. The polished face shows magnetite. It effervesces with muriatic-acid test.

A pinkish variety (specimens D, XXX, 113, a, d, e), "West Townsend red," is of light medium pinkish-gray color and of the same texture and composition

as the "white," but the thin section shows pyrite and what is possibly altered allanite, with radiating cracks filled with hematite stain.

This is a constructional and monumental granite of slightly coarser texture than the monumental granite of South Brookline, N. H., and probably of the same geologic age. South Brookline is only 4.4 miles east-northeast of this quarry. (See Groton topographic map and p. 192.) The stone takes a good polish.

The quarry, opened in 1907, measured in 1910 225 by 150 feet and 5 to 15 feet in depth.

Rock structure: The sheets, 1 to 5 feet thick, are about horizontal. There are no joints. The rift is horizontal and the grain vertical, with N. 80° W. course. A pegmatite dike up to 4 feet thick has a N. 55° W. course. There are also lenses of pegmatite. The inclusion of biotite or diorite gneiss referred to on page 63 came from below the quarry. Rusty stain is up to 6 inches thick.

Transportation, by cart one-third mile to railroad.

The product is used mostly for buildings but partly for monuments. Specimens: Entire front of Thames National Bank, Norwich, Conn.; trimmings to Alvirne Memorial Chapel, Hudson, N. H., post office, Nashua, N. H., and Thompson Memorial Chapel, Williams College, Williamstown, Mass.

NORFOLK COUNTY.

The quarries in Wrentham, Stoughton, and Cohasset are in two large areas designated on the map of Bulletin 597 "Dedham granodiorite (chloritic biotite granodiorite)" and described by Emerson on pages 175–177 of that bulletin.

WRENTHAM.

The **Curry quarry** is on High Rock, in Wrentham Township, about 2½ miles east-southeast of Wrentham station. (See Franklin topographic map, U. S. Geol. Survey, and Pl. XXIII.) Operator, High Rock Granite Co., Foxboro.

The granite (specimen D, XXX, 115, a), "Wrentham," is a hornblende granite of light-gray shade and of even-grained medium, inclining to coarse texture, with feldspars up to 0.5 inch and mica up to 0.1 inch. Its constituents, in descending order of abundance, are very light gray to pale cream-colored microperthite (potash feldspar, microcline and orthoclase, somewhat kaolinized, minutely intergrown with soda-lime feldspar); medium smoky quartz with abundant cavities in sheets; clear colorless to milk-white striated soda-lime feldspar (oligoclase-andesine), much kaolinized, also micacized and epidotized, in some crystals from within outward; and hornblende associated with epidote. Accessory: Magnetite. Secondary: Kaolin, a white mica, epidote, carbonate. Very slight effervescence with muriatic-acid test.

This is an attractive stone with marked mineral contrasts and is suitable for substantial structures. The quarry, opened in 1884, was in 1910 about 150 feet square and 25 to 35 feet deep.

Rock structure: The sheets, 4 to 16 feet thick (one a foot thick), are horizontal or dip 15° E. or W. and are likely to have 2 inches of decomposed granite between them. One set of joints, vertical, strike N. 10° E., spaced 2 to 100 feet, is coated with epidote. Another set, strike N. 60° E., dip 70° N. 30° W., forms headings of very close joints in the upper 10 feet of the rock. (See p. 38.) An obscure flow structure dips about 55° N. The rift is horizontal and the grain vertical, with N. 80° W. course. Knots are 1 to 6 inches in diameter. Rusty stain is 2 feet thick on the top sheet.

Transportation, by cart to local customers.

The product is used for building, curbing, and monuments.

STOUGHTON.

The **Messer quarry** is in the township of Stoughton, 1½ miles south of Stoughton Center, on Washington Street. Operators, Messer Bros., Brockton.

The granite, "Stoughton," is a biotite or hornblende granite of general medium-gray shade but mottled color and coarse texture, with feldspars to 0.5 inch and dark silicate to 0.1 inch. Its constituents in descending order of abundance are light pink potash feldspar (microcline and orthoclase); medium smoky, faintly amethystine quartz with cavities in sheets; pale-green to milk-white soda-lime feldspar (oligoclase-albite), much kaolinized and micacized; chlorite and epidote (after biotite or hornblende). Accessory: Pyrite, magnetite. Secondary: Kaolin. chlorite, epidote, limonite, a white mica calcite. Slight effervescence with muriatic-acid test.

The fresh rough face of this granite affords pleasant contrasts of color which are more marked on the polished face, but are too delicate to endure outdoor exposure.

The product is used for trimmings and tombs. Specimens: Trimmings on public library and Sampson Building, Brockton, and on Oakes Ames residence, Sharon; receiving tomb, Catholic cemetery, Stoughton.

COHASSET.

The **Tiffany quarry** is in the township of Cohasset. on Beechwood Avenue, about 2 miles southwest of Cohasset Station. Operator. Louis C. Tiffany. 46 West Twenty-third Street, New York.

The granite (specimens D, XXXVIII, 28; a, rough; b, polished). "Cohasset." is a biotite or hornblende granite of general medium-gray shade but mottled color and coarse texture, with feldspars to 0.5 inch and dark silicate to 0.2 inch.

Its constituents, in descending order of abundance, are pinkish potash feldspar (orthoclase, some of it minutely intergrown with a plagioclase); pale pea-green to cream-colored soda-lime feldspar (albite to oligoclase-albite), much kaolinized. micacized, and some of it epidotized; medium smoky quartz, faintly amethystine, with cavities in sheets; chlorite and epidote (after biotite or hornblende). Accessory: Magnetite. Secondary: Chlorite. epidote, kaolin, sericite, another white mica, calcite. Rift and grain cracks are marked.

The polished face is very attractive and by its variety of color well adapted for interior decoration.

The product is used entirely for monumental and memorial purposes and interior church work.

QUINCY, MILTON, AND BRAINTREE.

TOPOGRAPHY.

There is a conspicuous range of low hills south of Boston. known as the Blue Hills, which curves from Great Blue Hill, 11 miles south-southwest of the city, to Forbes Hill, 7½ miles south-southeast of it, and whose tops lie between the 180 and 640 foot levels. (See Boston and Dedham topographic maps, U. S. Geol. Survey.) The Quincy granite district lies at about the northeast end of this range, in the townships of Quincy, Milton, and Braintree, Norfolk County. Some of the quarries are on the North Commons from about half a mile west-southwest to a mile west of Quincy Center; others are in West Quincy from 1½ to 2 miles about west-southwest of the Center; two are in Milton, some 3 miles west of the Center; and one is in Braintree. Quarry locations are shown

on the map (Pl. XXIV). The reader will find some interesting historical matter on the Quincy quarries in a chapter on the early history of the granite industry in New England by George P. Merrill.[38]

GEOLOGIC RELATIONS.

The geology of the vicinity of Quincy and Boston is very complex and difficult and has long been under investigation and discussion by several resident and other geologists.[39]

The granite of Quincy was part of a great deeply buried mass of molten granitic material of various kinds, which was intruded in Carboniferous time into a considerable mass of overlying slates, etc., of middle Cambrian and possibly later age, which in places were entirely removed by subsequent erosion. That these slates were originally marine clayey sediments of middle Cambrian time is shown by the presence of fossil crustaceans typical of the middle Cambrian in some of them in the town of Braintree. After a long interval a large part of the region became again submerged during the Carboniferous period, and the advancing sea formed new sediments, but there was an interval of glaciation and the formation of till with pebbles from the exposed igneous and sedimentary rocks of Cambrian or post-Cambrian time.

This submergence continued until the conglomerate was overlain by a considerable accumulation of clayey sediments. During the post-Carboniferous crustal movement, which affected a large part of the continent, these clays became slate and were powerfully folded; basic dikes were also intruded into the granite and the overlying beds. The corrugation and elevation of the surface in post-Carboniferous time exposed the Carboniferous beds to erosion, so that portions of the granite surface which had been covered by them again became exposed. In Triassic time more basic dikes forced their way through fissures in the granite. Events in this region were further complicated by the occurrence of eruptions of very siliceous rocks at various points and times.

On the geologic map of the State in Bulletin 597 the quarries of the Quincy district are in a lenticular area, about 10 miles from east to west by half a mile to 2½ miles from north to south, of "Quincy granite (soda-rich riebeckite-bearing granite)," which in the text is regarded as of Carboniferous age. Lying within this area are several small areas of Braintree slate, of middle Cambrian age.

QUINCY GRANITE.

The following paragraphs epitomize the writer's descriptions of rough and polished specimens and thin sections of granite from all the quarries as given

[38] Smithsonian Inst. Rept., 1885-86, pt. 2, pp. 285-288.

[39] Crosby, W. O., Genetic and structural relations of the igneous rocks of the lower Neponset Valley, Mass.: Am. Geologist, vol. 36, pp. 39-41, 1905. Emerson, B. K., and Perry, J. H., The green schists and associated granites and porphyries of Rhode Island: U. S. Geol. Survey Bull. 311, p. 51, 1907. Crosby, W. O., The Bluehills complex: Boston Soc. Nat. Hist. Occasional Papers, No. 4, pt. 3, 1900 (includes Prof. Florence Bascom's work on the volcanic and plutonic rocks of the Boston basin). Mansfield, G. R., The origin and structure of the Roxbury conglomerate: Harvard Coll. Mus. Comp. Zoology Bull., vol. 49 (Geol. ser., vol. 8, No. 4), pp. 161, 259, pl. 6, 7, 1906. Loughlin, G. F., Structural relations between the Quincy granite and adjacent sedimentary formations: Am. Jour. Sci., 4th ser., vol. 32, p. 117, 1911. Sayles, R. W., The Squantum tillite: Harvard Coll. Mus. Comp. Zoology Bull., vol. 56, No. 2, pp. 141-175, 1914. Lahee, F. A., Late Paleozoic glaciation in the Boston Basin, Mass.: Am. Jour. Sci., 4th ser., vol. 37, p. 316, 1914. Emerson, B. K., Geology of Massachusetts and Rhode Island: U. S. Geol. Survey Bull. 597, pl. 10, pp. 186-191, 1917.

farther on. The more recent scientific accounts of this granite are by Wadsworth,[40] Merrill,[41] White,[42] Washington,[43] and Warren.[44]

Quincy granite is a riebeckite-aegirite granite. Riebeckite and aegirite are varieties of amphibole and pyroxene, respectively, both rich in soda (8 to 10 per cent) and in iron sesquioxide (about 28 per cent) but poor in alumina, magnesia, and lime. The general color of the fresh normal granite ranges from a medium gray or bluish or greenish or purplish gray to a very dark bluish gray, all with black spots which, on closer inspection, are seen to be blue-black or green-black or a mixture of both. Its texture is medium to coarse and even grained, with feldspars up to 0.4 and 0.5 inch and the black silicates up to 0.3 and 0.4 inch. Its constituents, in descending order of abundance, are these: (1) A medium to dark bluish or greenish to bluish gray feldspar (orthoclase, much of it twinned), always with minutely intergrown soda-lime feldspar (albite to oligoclase-albite). It is apparently more or less darkened by a varying number of extremely minute particles of a black mineral, which are not absolutely distinguishable from opaque particles of kaolin, and is always slightly tinted by minute particles of grass-green aegirite and whitened by partial kaolinization or black streaked by clusters of radiating fibrous crystals of dark-brown hornblende. The fresh feldspar always contains crystals of blue-brownish riebeckite from 0.01 to 1.0 millimeter long by up to 0.01 millimeter in width. These crystals, and also the aegirite, are in many specimens arranged in two rectangular directions, one that of the twinning plane, the other that of the intergrown soda-lime feldspar. In some sections (p. 327) the feldspars were found crossed by rift and grain cracks filled or overlain by minute crystals of riebeckite, thus evidently of secondary origin like those on joint planes described on page 82. (2) Medium to dark smoky quartz, some of it with a slight bluish tinge. It contains cavities (many with liquid and movable vacuoles) arranged in streaks and sheets and measuring from 0.0028 to 0.02 millimeter in length. This quartz also incloses minute black particles and in places hairlike crystals, presumably of rutile, more rarely minute crystals of riebeckite, one measuring 0.178 by 0.0047 millimeter. (3) A little lime-soda feldspar (albite to oligoclase-albite). (4) Riebeckite (blue-black in hand specimen but Prussian blue and brownish gray in thin section) and aegirite (green-black in hand specimen but light green to emerald-green in thin section), both minerals in many specimens intergrown. The aegirite may surround riebeckite, or these relations may be reversed. In some specimens riebeckite in slender crystals appears like a secondary growth on aegirite. In others the aegirite appears as filling spaces between the other minerals. Basal sections of it appear as if corroded. All of the riebeckite can not be secondary, because it appears in minute crystals within the quartz and forms the center of large crystals of aegirite. Nor can all the aegirite be secondary, because crystals of it also occur within quartz particles and also surrounded by radiating crystals of riebeckite. (See p. 327.) The aegirite is likely to contain particles of magnetite and carbonate.

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[40] Wadsworth, M. E., Notes on the petrography of Quincy and Rockport: Boston Soc. Nat. Hist. Proc., vol. 19, pp. 309–316, 1881.

[41] Merrill, G. P., The collection of building and ornamental stones in the United States National Museum: Smithsonian Inst. Rept. for 1885–86, pt. 2, pp. 409, 418.

[42] White, T. G., A contribution to the petrography of the Boston Basin: Boston Soc. Nat. Hist. Proc., vol. 28, pp. 128–132, 1897.

[43] Washington, H. S., Sölvsbergite and tinguaite from Essex County, Mass.: Am. Jour. Sci., 4th ser., vol. 6, p. 181. 1898.

[44] Warren, C. H., Petrology of the alkali-granites and porphyries of Quincy and the Blue Hills, Mass.: Am. Acad. Arts Sci. Proc., vol. 49, No. 5, pp. 203–330, 1913.

The accessory minerals are ilmenite, magnetite (probably), pyrite (very rare), zircon in doubly terminated crystals, fluorite, titanite, and the minute black particles in quartz. The secondary minerals are kaolin, yellow-brown to orange hornblende in fibrous crystals, chlorite, calcite, leucoxene, hematite, limonite (associated with zircon and aegirite), and part of the riebeckite. One of the altered granites (Sartori quarry) contains spherulites which polarize like zircon. Another one (Savo quarry) is cut by a veinlet of secondary epidote, quartz, and calcite.

Estimates of the mineral percentages by the Rosiwal method yield the following figures for the "medium," "dark," and "extra dark:"

Estimated mineral percentages in Quincy granite.

	Average.
Feldspars, 55.80 to 69.51	60.02
Quartz, 22.06 to 33.74	30.60
Riebeckite and aegirite, 7.47 to 11.10	9.37

Of course the microscopic particles of the soda-iron silicates are not included in these figures.

The following analysis of Quincy granite by Henry S. Washington[45] was published in 1898:

Analysis of riebeckite-aegirite granite from the Hardwick quarry, Quincy, Mass.

Silica (SiO_2)	73.93
Titanium dioxide (TiO_2)	.18
Alumina (Al_2O_3)	12.29
Iron sesquioxide (Fe_2O_3)	2.91
Iron oxide (FeO)	1.55
Manganese oxide (MnO)	Trace.
Magnesia (MgO)	.04
Lime (CaO)	.31
Soda (Na_2O)	4.66
Potash (K_2O)	4.63
Water above 110° (H_2O)	.41
	100.91

Specific gravity 2.642 at 22° C.

Two later analyses of the same granite, but from the Hitchcock and the Reinhalter quarries, by C. H. Warren[46] differ but little from the above.[47]

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[45] See Am. Jour. Sci., 4th ser., vol. 6, p. 181, 1898; also Jour. Geology, vol. 6, p. 793, 1898.

[46] Op. cit., p. 227.

[47] For analyses and optical features of riebeckite and aegirite see Rosenbusch, H., Mikroskopische Physiographie der Mineralien und Gesteine, 4th ed., vol. 1, pt. 2. pp. 213, 244, 1905; for discussion as to their origin see Murgoci, G. M., On the genesis of riebeckite and riebeckite rocks: Am. Jour. Sci., 4th ser., vol. 20, pp. 133–145, 1905; and Cross, Whitman, On some secondary minerals of the amphibole and pyroxene group: Am. Jour. Sci., 3d ser., vol. 39, pp. 359–370, 1890. Murgoci (op. cit., p. 138) sums up the views on the origin of these two minerals thus: "Some petrologists have considered the aegirite as a transformation product of riebeckite, and others have taken the riebeckite for a secondary product of aegirite. Most petrologists state, however, that riebeckite and aegirite are primary in their rocks." On the next page in a footnote he adds: "The best argument for the primary existence of the aegirite is its occurrence in the same rock, with little thin needles of riebeckite, which could not resist even the slowest and slightest action of transformation."

E. C. Sullivan and G. Steiger, chemists, of this Survey, extracted by means of hot dilute acetic acid 0.11 to 0.28 per cent of CaO (lime) from specimens from four quarries in Quincy and Milton. This lime indicates the presence of 0.196 to 0.50 per cent of $CaCO_3$ (calcium carbonate) or calcite.

Quincy granite for monumental purposes goes under the names "medium," "dark," and "extra dark." The estimated mineral percentages show that these differences in shade are due in part to a variation in the amounts of the black silicates and of the smoky quartz. In part they are also due to a variation in the degree of kaolinization of the feldspars and in the abundance of black particles and of hornblende in them. The smokiness of the quartz appears to be due to infinitesimal particles of some black mineral. The bluish tint of the feldspars is due to microscopic crystals of riebeckite and its greenish hue to minute aegirites. The contrast of color and shade is chiefly between the black silicates and the combined quartz and feldspar except where the feldspar is whitened by kaolinization, which causes it to stand out from the quartz. "Light Quincy granite," which is of medium-gray shade, is considered second grade and sells for rock face and hammered work.

Quincy granite is noted for its high polish, which comes out strikingly on columns and balls, as shown in Plate XXVI. This susceptivity to high polish is due to the absence of mica and to the coarser cleavage of the varieties of hornblende and augite which take its place. The imperfections that occur in the polish of some blocks are due to particles of aegirite partly altered before quarrying. (See p. 79.)

A peculiar variety of Quincy granite, known as "Gold leaf," described on page 332, is the lightest monumental stone quarried there. Its general color is medium bluish green-gray, speckled with black and light yellow-brown. The quartz, clear to light smoky, is finely granular, like that of Milford, Mass., and sparkles on the polished face. Wherever the yellow spots, which are caused by limonite stain, coincide with the granular quartz, they are more conspicuous. In other respects its constituents are identical with those of the riebeckite-aegirite granite of Quincy. A minor variety is that of the Ballou quarry, which has sparsely disseminated minute cherry-red dots, probably from the oxidation of magnetite particles.

A recently opened quarry in Braintree (p. 335) yields a medium reddish-gray variety with much kaolinized, slightly hematitic feldspars and decomposed ferrosilicates.

Other and cheaper varieties of Quincy granite are suitable only for building purposes. Such are the "extra light" (pea-green), the pink, and the greenish brown, described on pages 330, 331, 335. The "oreï" (hematitic) finds its way to the dumps. These various colors are due either, as in the pea-green, to the presence of fine particles of aegirite in the feldspars, or else to changes in the feldspars or aegirite, brought about by underground alterations which have been long in process. (See further p. 77.) The yellow, rusty discoloration (sap) referred to on page 67 is of still later date, affecting the stone for a few inches only along the sheet and joint surfaces.

GEOLOGY OF QUINCY QUARRIES.

The cylindrical pegmatite dikes with large aegirite crystals at the Ballou and Fallon quarries, first studied by Charles Palache, have already been described on page 49. Certain pegmatitic quartz veins have been described on page 51. The basic dikes at the Granite Railway and Merry Mount quarries have been referred to on page 52. Others were observed at the Winquist and Dell Hitchcock quarries. The segregations (knots) have been described in a

general way and classified on page 59. They have been exhaustively treated by Warren in the work cited.

Rift in the Quincy quarries is reported as generally vertical or nearly so, with a course from N. 65° W. to due west, and the grain as vertical or nearly so and about north to south. The grain is generally feeble. Rift courses of north, N. 10° E., and N. 30° W., are reported at a few quarries, and at three the grain is reported as horizontal. At the Swingle quarry, which is crossed by a diagonal heading striking north, the rift is reported to be north-south on the west side of that heading but east-west on its east side. The angle of inclination of both rift and grain is reported as subject to modifications, some of which are probably only local; others are due to general physical principles. At the Reinhalter quarry the rift is vertical below but not quite vertical near the surface. Mr. Cashman stated that in his quarry the grain is 90° when the sheet is split from the top, but if split from the side it is steeply inclined. Mr. Galvin reported that the grain is horizontal when the drilling is done from east to west, but dips 20° when it is done from north to south. The degree of dip of rift and grain is affected by gravity—that is, it is proportioned to the weight of the block on one side or the other of the fracture. Two foremen find that when the sheets are inclined the dip of the rift swerves from the vertical. At the Field & Wild quarry rift and grain are reported as varying greatly in different blocks. The subject of rift will be found more fully discussed on page 15, and its apparent relation to the sheets of fluidal cavities is explained on page 17.

The crushing of cores between drill holes made in channelling shows that the Quincy granite mass is now under compressive strains from the north and south and the east and west. This strain in some quarries appears to increase with their depth. At one quarry not only are north-south channels closed by it, but diagonal subjoints are started from the channels.

Sheet structure in Quincy is regular in places, as at the Dell Hitchcock quarry (Pl. XXV, *A*), where it consists of lenses with an undulating course usually parallel to the rock surface and increasing in thickness downward. But it is more commonly obscure and irregular owing to the shortening and thickening of the lenses, which results in "boulder quarries." Sheet structure extended in 1906 to a depth of 150 feet from the rock surface at the Ballou quarry on the North Commons and to a depth of 175 feet in the Reinhalter quarry in West Quincy, but in 1917 it reached a depth of 250 feet. The inclination of the sheets is in places as high as 45°, and their thickness ranges from 6 inches to 27 feet. They are rarely intersected by sharp curving joints or partings known as "toenails." The origin of sheet structure has been fully discussed on pages 26–36. In quarrying it is safe to count on a gradual increase in the thickness of the sheets downward. If for a space thin sheets recur they may be expected to give way to thicker ones below. The quarry adjacent to the Dell Hitchcock is reported to have been abandoned because of the appearance of thin sheets below and the assumption that they would not be succeeded by thicker ones. At the Reinhalter quarry, which in 1906 was 225 feet deep, the lowest sheet was over 45 feet thick. Mr. J. S. Swingle reports that his quarries have now reached a depth of about 250 feet without reaching the limit of sheet structure.

The general character of the jointing can be inferred from the quarry diagrams (figs. 71–74). The principal joint sets are: (a), striking N. 60°–85° W. to N. 83° E., and its complementary set (b), north to N. 20° E.; a single set (c), striking N. 10°–30° W.; and (d), striking N. 25°–55° W., with its complementary set (e), N. 45°–50° W. A noticeable feature in some of the deeper quarries is the vertical discontinuity of the headings. Some of the

MAP OF QUINCY, MASS., SHOWING LOCATION OF GRANITE QUARRIES.

1, Wigwam; 2, Reinhart; 3, Swingle; 4, Granite-Railway; 5, Lepage; 6, Cashman; 7, Gold-leaf; 8, Savo; 9, Rogers; 10, Maguire & O'Heron; 11, Mount Pleasant; 12, Sartori; 13, Dell Hitchcock; 14, Merry Mount; 15, Ballou; 16, Winquist (2 quarries); 17, Sahlsten; 18, Falconer; 19, Hardwick; 20, Field & Wild; 21, Fuller; 22, Fallon.

A. DELL HITCHCOCK QUARRY, QUINCY, MASS., FROM WEST SIDE.

Showing lenticular sheets increasing in thickness downward. Depth 100 feet.

B. MONUMENT OF POLISHED DIABASE PORPHYRY FROM PIGEON COVE, ROCKPORT, MASS.

Diameter of ball, 2 feet 7 inches.

BALL OF POLISHED QUINCY GRANITE.

From Wigwam quarry, Quincy, Mass. Diameter, 76 inches; weight, 22,000 pounds.

A. PIGEON HILL UPPER QUARRY, ROCKPORT, MASS., LOOKING SOUTHWEST.

Showing thick granite sheets cut by basic dikes. The black streaks in the front dike are underground water issuing from sheet surfaces through cracks in the dike.

B. DEEP PIT GRANITE QUARRY, NEAR BAY VIEW, ROCKPORT, MASS., LOOKING NORTH.

Showing in upper part thick faulted dike of hornblende diabase, cut along fault plane by a thin dike of lamprophyre without biotite, reaching to bottom at left; also, in the center below, an irregular injection of hornblende diabase. Some of the joints are parallel to

bottom ones disappear upward within 100 feet of the surface; others which occur at the surface disappear below. Some of the joints are also intermittent. The possibility of a bad heading dying out below is as encouraging to the quarryman as the possibility of the appearance of a new one below is discouraging. This discontinuity in the joints and headings reflects the complex character of the stresses to which the region was exposed.

The remarkable black joint coatings of riebeckite have been described on page 82. At one of the Milton quarries this appears on the sheet surfaces also, and the adjacent granite is lighter in shade.

From these summaries on the granite and on its geology as exposed at the quarries the following inferences may be drawn: The riebeckite-aegirite granite of Quincy had aegirite as one of its original constituents and riebeckite as another, but some of the riebeckite is clearly secondary, as shown by its occurrence in rift cracks and on sheet and joint faces. The formation of this mineral on these faces indicates that the granite after acquiring its sheet and joint structure was subjected to metamorphism, probably that which accompanied the post-Carboniferous crustal movement. The source of this secondary riebeckite may well have been the aegirite itself. The hematite-spotted granite ("oreï"), the pink granite, and the greenish-brown granite (described on pp. 79, 331, 335), while evidently due to the alteration of the aegirite particles to magnetite, hematite, green hornblende, biotite, and chlorite, owe these mineral changes partly to processes of deep-seated alteration and partly to regional metamorphism, and the pea-green variety is due to the dissemination of fine prisms and grains of aegirite in its feldspars. In the dull-reddish granite of Braintree (p. 335) the aegirite and riebeckite seem to have been decomposed and the feldspars kaolinized and reddened by secondary hematite. The latest change was the brownish iron staining along sheet and joint surfaces, which is attributable to percolating surface water oxidizing the magnetite and soda-iron silicates and possibly also adding fresh supplies of iron sesquioxide obtained from deposits once overlying the granite.

QUARRIES.

The **Dell Hitchcock quarry** is on the North Commons, south of Quarry Street. (See map, Pl. XXIV, No. 13.) Operator, Quincy Quarries Co., Quincy.

The granite (specimen D, XXVIII, 67, d), "dark Quincy," is a riebeckite-aegirite granite of somewhat dark and slightly bluish-gray color with black spots. Its texture is medium to coarse, even grained, with feldspar up to 0.5 inch and black silicates usually not over 0.3 but occasionally 0.5 inch. Its constituents, in descending order of abundance, are a medium bluish and greenish gray potash feldspar (orthoclase), usually twinned, minutely intergrown with soda-lime feldspar and inclosing minute crystals of riebeckite and grains of aegirite and in places somewhat kaolinized; smoky quartz with cavities (some with liquid and vacuoles) and black particles in streaks or sheets; a little separate soda-lime feldspar (albite to oligoclase-albite); aegirite, much of it intergrown with riebeckite. Accessory: Magnetite, zircon, fluorite. Secondary: Kaolin, calcite, brown fibrous hornblende, and chlorite in rift cracks in feldspar.

The contrast in the rough stone is entirely between the black silicates and the combined quartz and feldspar.

A specimen (D, XXVIII, 67, c) of the "light Quincy" is more of a medium gray with a slight greenish tinge. Its general composition is the same as that of the "dark Quincy," with probably more kaolin and aegirite in the feldspars. The contrasts are more marked.

The quarry, opened before 1826, is about 500 feet N. 25° E. by 500 feet N. 65° W. and in 1906 was 100 feet deep. (See Pl. XXV, *A*).

Rock structure: The sheets, 6 inches to 12 feet thick, are lenticular, undulating horizontally. As shown in the plate the upper 30 feet consists of very thin sheets which, owing to their thinness and rustiness, are valueless. Joints (a) strike N. 70° W., dip 90°, and are spaced irregularly, but nowhere completely cross the quarry. A set with similar strike, but dipping 30°–35° NNE., is represented. Joints (c) strike N. 20° W., dip 90°, and are spaced 14 to 30 and 400 feet. At the bottom there are short intermittent joints dipping east and in other directions, which are coated with riebeckite and thus have blue black surfaces. (See p. 82.) The rift is reported as vertical, with a N. 65° W. course, and the feeble grain as at right angles to it and vertical. A dark bluish-gray knot (67, e) contains porphyritic crystals of aegirite, as described under group 1 on page 59. There are also some of group 3. The boundaries between the "light" and "dark" granite are not well defined. Rusty discoloration is 2 to 18 inches thick. Where it is only 2 inches there is a zone of incipient stain several inches thick.

Transportation, by cart three-fourths mile to railroad and about a mile to local cutting sheds.

Specimen: Three bases and die of the Jefferson monument at Louisville, Ky.

The **Merry Mount quarry** is on the North Commons, north of Quarry Street. (See map, Pl. XXIV, No. 14.) Operator, Merry Mount Granite Co., Quincy. Idle since 1914.

The granite (specimen D, XXIX, 86, a), "dark medium Quincy," is a riebeckite-aegirite granite of somewhat dark, slightly purplish-gray color, slightly darker than that of 67, d. The texture is medium to coarse, even grained, with feldspar up to 0.5 inch and black silicates up to 0.3 inch. Its constituents, in descending order of abundance, are a medium and dark or slightly greenish-gray potash feldspar (orthoclase, generally twinned), always minutely intergrown with soda-lime feldspar (albite to oligoclase-albite), in places somewhat kaolinized and inclosing riebeckite crystals up to 0.094 by 0.0094 millimeter and minute grains of aegirite; also hematite stain; smoky quartz with streaks or sheets of cavities and minute black particles; a little separate soda-lime feldspar (oligoclase-andesine); blue-black riebeckite and green-black aegirite, either separate or intergrown. Accessory: Zircon (abundant in crystals up to 0.47 millimeter), fluorite. Secondary: Kaolin, limonite, hematite.

The purplish tinge of this granite is evidently due to hematite in the feldspar. The contrast in the rough stone is entirely between the black silicates and the general gray of the quartz and feldspar.

E. C. Sullivan, chemist, of this Survey, extracted 0.11 per cent of CaO (lime) from this granite by means of hot dilute acetic acid, which indicates the presence of 0.19 per cent of $CaCO_3$ (calcium carabonate, calcite). The thin sections also show calcite.

A specimen of "medium Quincy" (D, XXIX, 86, b) is a trifle lighter in color and has a slightly greenish tinge. Its texture and constituents are the same, except that the feldspar borders on light gray and hematite stain is absent. The quartz is darker than much of the feldspar.

The quarry, opened in 1856, measured in 1906 about 300 feet from north to south by 200 across and from 130 to 150 feet in depth.

Rock structure: On the west wall is a 5-foot dike of lamprophyre, described on page 53, which strikes N. 10° E. The sheets are lenticular in all directions and mainly horizontal, 1 to 16 feet thick. They thicken downward, but with thin sheets at intervals, to a depth of 40 feet. Joints (b) strike N. 10° E., dip 90° or steep west, are spaced 5 to 20 feet, and form a heading near the

dike. One diagonal joint (d) strikes N. 50° E. and dips 70° NW. The rift is reported as striking N. 10° E. and vertical or dipping steeply west, and the grain as east, dipping steeply north. In individual blocks the rift is considerably affected by gravity. Knots, both dark and light, are 1 to 6 inches across, but some are reported as 2 feet 6 inches in two diameters. Rusty stain on sheet surfaces is 1 to 6 inches thick.

Transportation, by cart 1 mile to railroad or cutting shed.

The product consists chiefly of the "dark medium." Specimen: Barney mausoleum at Springfield.

The **Ballou quarry** is on the North Commons, north of Quarry Street. (See map, Pl. XXIV, No. 15.) Operator, John C. Ballou, West Quincy.

The granite (specimen D, XXIX, 80, a), "dark Quincy with minute red dots," is a riebeckite-aegirite granite of dark, slightly purplish-gray color, with sparse inconspicuous reddish stains. Its shade is slightly darker than that of 86, a (Merry Mount "dark medium"). Its texture is medium to coarse, even grained, with feldspars up to 0.5 inch and black silicates to 0.3 inch. Its constituents, in descending order of abundance, are a dark-gray potash feldspar (orthoclase), twinned, minutely intergrown with soda-lime feldspar, in places somewhat kaolinized, rarely with hematite stain along its cleavage planes, and inclosing grains of aegirite and crystals of riebeckite up to 0.114 millimeter long; smoky quartz of very slight bluish tinge, with abundant cavities up to 0.0094 and exceptionally 0.037 millimeter in diameter, in streaks or sheets intersecting one another at all angles, and with very minute black particles; the quartz incloses a riebeckite crystal 0.178 by 0.0047 millimeter; a little separate soda-lime feldspar (albite to oligoclase-albite); and finally riebeckite, some of it intergrown with aegirite, the latter containing magnetite and carbonate. Accessory: Zircon, magnetite. Secondary: Kaolin, hematite, limonite (about the zircon), calcite.

The contrast is confined to that between the black silicates and the dark gray of the feldspar and quartz with its faint reddish spots.

George Steiger, chemist, of this Survey, extracted 0.28 per cent of CaO (lime) from this stone by means of hot dilute acetic acid, which indicates a content of 0.5 per cent of $CaCO_3$ (calcium carbonate, calcite). The thin sections also show calcite.

The quarry, opened before 1856, measured in 1906 about 200 feet from north to south by 100 feet across, but with a recess on the south wall 16 by 18 feet. Its depth was 150 feet.

Rock structure: An interesting cylindrical pegmatite dike, a section of which is exposed at the bottom of the quarry, has been described on page 49. The sheets, 8 inches to 20 feet thick, increasing in thickness downward, are lenticular, irregular, and dip both north and south. The sheet structure extends at least to a depth of 150 feet from the rock surface, below which there is no parting for 16 feet. Joints (a) strike about N. 80° W., dip 70° N., are spaced 3 to 30 feet, form a short heading in about the center and one on the northeast side. Joints (b) strike nearly north, dip 90° and steeply west, form headings at east and west walls, one, 100 feet from west wall, and another (30 to 40 feet wide) 75 feet west of east end. Joints (c), striking N. 10°–30° W., form a heading at the northwest corner at the quarry. The rift is reported as about north, and the grain as east, both vertical. Stain is up to 3 inches wide along the joint faces but is scarcely present on sheet surfaces.

Transportation, by car 1 mile to railroad.

The product is used mainly for monuments, and the inferior stock for paving. Specimen structure: Masonic Building, Philadelphia.

The **Winquist quarries** are on the North Commons south of Quarry Street. (See map, Pl. XXIV, No. 16 and opening west of it.) Operator, Common Quarry Co. (Carl G. Winquist), Quincy.

The granite of the Baker opening (No. 16), alone operated in 1906, "extra light," is a riebeckite–aegirite granite of light pea-greenish color and medium to coarse texture. It is identical in composition with that of the Lepage quarry (specimen D, XXVIII, 76, a), described on page 330. It owes its green color to the abundance of minute grains and crystals of aegirite in the feldspar. The quartz is amethystine, not smoky. The contrast is chiefly between the black silicates and the feldspar, but there is also some between the purple tinge of the quartz and the light green of the feldspar.

This stone was used entirely for building and hammered work.

The granite of the McDonald opening (west of No. 16) consists of light and dark "medium" and "dark" Quincy and is used for monuments, etc.

The Baker opening measures about 300 by 250 feet and 125 feet in depth; the McDonald opening about 200 by 150 and 100 in depth.

Rock structure (Baker opening): There is a basic dike 6 feet thick, along the south side, dipping steeply south; a like one a little north of the north wall dips steeply north. The sheets, 2 to 22 feet thick, dip low north. Joints are few. Joints (a) strike nearly east, steep, form north and south walls only. Joints (b) strike nearly north, form east and west walls only; one diagonal (e), strike northwest, dips 45° SW. Rusty stain is up to 6 inches thick on sheet surfaces.

Transportation, by cart 1 mile to railroad.

The **Fallon quarry** is on the North Commons, on the south side of Quarry Street, west of the Hardwick quarry. (See map, Pl. XXIV). Operators, John Fallon & Sons, West Quincy. Idle since 1916.

The granite is "dark medium Quincy."

The quarry measures about 600 by 100 feet and 100 feet in depth.

Rock structure: In this quarry a cylindrical dike of pegmatite, like that at the Ballou quarry, was discovered a few years ago. (See papers by Warren and Palache, cited on page 49.)

Specimen product: Pilgrim Monument (excluding statue), Plymouth.

The **Hardwick quarry** is on the North Commons opposite the corner of Quarry and Smith streets. (See map, Pl. XXIV, No. 19.) Operators, C. H. Hardwick & Co., Quincy.

The granite (specimen D, XXIX, 79, d), "medium," is a riebeckite-aegirite granite of dark, slightly purplish gray color, a trifle darker than 86, a (the "dark medium" of Merry Mount quarry) and a little darker and more purplish than 67, d (the "dark" of Dell Hitchcock quarry). It is of medium, even-grained texture, with feldspars and black silicates up to 0.4 inch. Its constituents, in descending order of abundance, are a medium and dark, slightly purplish-gray potash feldspar (orthoclase), usually twinned, always with minutely intergrown soda-lime feldspar and exceptionally with quartz also; in places it is somewhat kaolinized, contains minute aegirites and crystals of riebeckite from 0.0094 to 0.066 millimeter long up to 0.0094 millimeter wide; light smoky quartz with intersecting streaks or sheets of cavities from less than 0.0043 to 0.02 millimeter long, also with very minute black particles; riebeckite and aegirite, the latter with black nonmetallic particles (limonite?); a little soda-lime feldspar (albite to oligoclase-albite.) Accessory: Magnetite. Secondary: Kaolin, brownish-yellow fibrous hornblende on riebeckite, limonite (?).

The contrast is largely between the black silicates and the gray of the quartz and feldspar.

The "light" of the same quarry (specimen D, XXIX, 79, f) is a similar granite of medium gray, inclining to dark shade without bluish or greenish or purplish tinge, with blue-black and very dark green spots, and of medium texture, with feldspar and riebeckite up to 0.4 inch. Its constituents are identical with those of the "medium" already described, except that the feldspar is in places stained with hematite, in others with limonite, proceeding from limonite associated with zircon, and that the aegirite appears to be slightly altered. There is some leucoxene adjacent to ilmenite. The aegirite contains not a little magnetite. Fluorite is among the accessory minerals.

The contrast between the black silicates and the other minerals in the "light" is greater than in the "medium," because the feldspars are lighter.

The "dark" (specimen 79, e) is darker than the "medium" and of the same shade as the "dark" of the Granite Railway quarry (68, b), page 329, but of marked purplish tinge. Its texture is medium to coarse.

An analysis of a granite from this quarry is given on page 318.

The quarry, first opened in a small way in 1790, but first operated by the Hardwick family in 1848, measured in 1906 about 300 feet east and west by 150 feet across, and has now reached a depth of 150 feet.

Rock structure: The sheets, 8 inches to 20 feet thick, usually increasing in thickness downward, but in places thin to a depth of 50 feet, are lenticular and horizontal. Joints (a) strike N. 80°–85° W., dip 55°–65° N., spaced 10, 30, and 60 feet, form a heading on the west wall. Joints (c) strike N. 30° W., dip 70° SW., spaced 5, 25, and 150 feet, form a heading 30 feet wide in east half of quarry. These joints are intermittent. The rift is reported as vertical, with a course about N. 30° W., and the grain as horizontal. The boundary between the "medium" and the "light" is irregular. Within the headings the stone has a marked purplish tint from hematite stain. There are rows of riebeckite particles up to 0.5 inch wide with a N. 85° W. course and a dip of 55° S. There are also quartz veinlets with a N. 20° W. course, less than 0.1 inch thick, which in places give way to black silicates. In thin section this black part consists chiefly of quartz, aegirite, and magnetite, with a little zircon (in doubly terminated pyramids), purple fluorite, and carbonate. Aplitic knots of group 1, described on page 59, are up to 3 feet by 4 inches. Light-gray knots of group 2, with porphyritic feldspar, occur also. Rusty stain along the sheet surfaces is from three-fourths inch to 6 inches thick.

Transportation, by cart 1 mile to railroad and varying distances to local cutting sheds.

The product is chiefly the "medium" but includes some "dark" and "light," the last used for bases and hammered work. Specimens: Addition to Gore Hall at Harvard University, erected in 1870; customhouse at New Orleans; Lewis Cass monument at Detroit, Mich.; a 5-foot polished ball in Fairmount Cemetery, Newark, N. J. The firm supplies rough stock to concerns that finish it.

The **Galvin quarry** is on the North Commons, between the Falconer and the Hardwick quarries. (See map, Pl. XXIV.) It is now abandoned.

The granite is a riebeckite-aegirite granite of dark or medium gray color.

Rock structure: There are pegmatite quartz veins at intervals of 2 to 10 feet, striking N. 25° W. and dipping 50° S. 65° W. These veins, up to 1 inch thick, occupy the center of belts of light granite 10 inches wide and are crossed by vertical subjoints striking about north and not over 1 foot long. (See p. 40.)

The product is carted to local cutters.

The **Falconer quarry** (formerly McKenzie & Pattison) is on the North Commons. (See map, Pl. XXIV, No. 18.) Operators, Falconer & Co., Quincy. This has on its northwest side quartz veins, like those of the Galvin quarry,

striking N. 50° W. and dipping 50° S. 40° W. forming the center of bands of whitish and brownish discoloration.

The quarry is 400 by 250 feet and 100 feet deep.

The product is used for tombs and cemetery monuments.

The **Field & Wild quarry** is on the North Commons between the Falconer quarry and Cranch Street. (See map, Pl. XXIV, No. 20.) It is now abandoned.

The granite, "dark," "medium," and "light," is a riebeckite-aegirite granite of dark and medium gray shades.

The quarry, opened about 1840, measured in 1906 about 600 feet from northwest to southeast by 150 feet across and from 75 to 100 feet in depth.

Rock structure: The rock surface on the northeast side dips steeply east, with sheets from 1 to 3 feet thick parallel to it. Some thin sheets occur also in the upper 20 feet on the southwest side. Joints (b), strike N. 15° E., dip 90° or steep, spaced 10 to 50 feet, occur at the northwest end only; joints (c), strike N. 15° W., dip 80° E., spaced 1 to 8 feet; joints (d), strike N. 45° E., dip 70°–85° N. 45° W., spaced 20 to 50 feet; (e), strike about N. 45° W., dip 30°–50° S. 45° W., spaced 2 to 8 feet. Some intermittent joints are coated with riebeckite. The rift is said to vary greatly in direction both in the quarry and in different blocks. Numerous quartz veins like those at the Galvin and Falconer quarries strike about N. 45° W., dip 45° S. 45° W., spaced 2 to 25 feet. They are mostly crossed by subjoints 1 foot long, parallel to joints (c), an inch or two apart. Some of them have a central fracture. In places they are only 0.02 inch thick. A thin section of one shows quartz crowded with cavities in intersecting streaks, crystals of ilmenite (probably), and carbonate. The hand specimen shows fluorite along the edge of the vein. The feldspars adjacent to the vein are traversed by fibrous muscovite, also kaolinized, stained with limonite, and otherwise altered. (See p. 77.) Knots up to more than 6 inches, some of them of group 2 (p. 59), with porphyritic feldspars, occur.

The **Wigwam quarry** is on Willard Street, 570 feet south of West Quincy Station. (See map, Pl. XXIV, No. 1.) This quarry was operated in 1906 by Badger Bros., but is now abandoned.

The granite, chiefly "dark" and "extra dark," with some "medium" and "light," is a riebeckite-aegirite granite of dark, very dark, or medium bluish-gray color and of medium to coarse, even-grained texture. Its constituent minerals are similar to those of specimens D, XXVIII, 68, b ("dark"), and D, XXIX, 78, a ("extra dark"), described on pages 327, 329.

A polished specimen (D, XXVIII, 73, a) of the "medium" shows the feldspars ranging from a dark gray to a greenish medium gray, and cream-colored in spots owing to kaolinization. The contrasts between the black silicates, the grayish quartz and feldspars, and the cream-colored parts of the feldspars are marked and give the stone a mottled appearance.

An estimate of the mineral percentages made by applying the Rosiwal method to this specimen, with a mesh of 0.6 inch and total linear length of 20.4 inches, yields these figures: Feldspars, 69.51; quartz, 8.43; riebeckite and aegirite, 22.06.

The quarry, opened between 1820 and 1830, measured, in 1906, about 250 feet in a N. 65° W. direction, by 100 feet across, and from 100 to 160 feet in depth.

Rock structure: The sheets at the surface, on the north and west sides, 1 to 3 feet thick, dip 50° NE. On the south and east sides there are traces of sheet structure in the upper 40 feet but none below that. Joints (a), strike N. 83° E. and vertical, are spaced 6 to 20 feet. Joints (b), strike N. 10° E. and vertical, are spaced 3 to 18 feet and form the southwest wall. Owing to its irregular sheets and the spacing of the joints this is technically a "boulder quarry." The rift was reported as vertical, with an east-west course on the south side,

but on the north as dipping steeply north, and the grain as vertical north to south. Black knots are reported up to 6 by 2 feet. Greenish and muddy yellow knots of group 3, page 59, measure up to 1 foot in length by a few inches in width. Reddish and greenish spots ("oreĭ," p. 78) occur in the upper 30 feet.

The product consisted chiefly of the "dark" and "extra dark" for monuments. Specimens: Polished columns in monument to Solomon Willard, architect of Bunker Hill Monument, in Hall Cemetery, West Quincy; polished columns in New Orleans customhouse; polished ball, 6 feet 6 inches in diameter, in cemetery at Rock Island, Ill., a photograph of which is reproduced in Plate XXVI.

The **Reinhalter quarry** is 570 feet south-southwest of West Quincy station. (See map, Pl. XXIV, No. 2.) Operator, J. S. Swingle, Quincy.

The granite (specimen D, XXIX. 78, a), "extra dark," is a riebeckite-aegirite granite of very dark bluish-gray color and of medium to coarse, even-grained texture, with feldspars up to 0.5 inch and black silicates up to 0.3 inch. Its constituents, in descending order of abundance, are a dark and medium gray potash feldspar (orthoclase), mostly twinned, minutely intergrown with soda-lime feldspar, darkened probably by a black mineral in very minute particles; it incloses minute crystals of riebeckite and grains of aegirite; smoky quartz with intersecting streaks and sheets of cavities, very minute black particles and isolated crystals of aegirite; blue-black riebeckite and green-black aegirite, in places intergrown; a little separate soda-lime feldspar (albite to oligoclase-ablite.) Accessory: Zircon (rather abundant), ilmenite, and pyrite. Cracks in orthoclase and quartz, intersecting at right angles, probably rift and grain cracks, contain or are crossed by secondary minute crystals of riebeckite. The feldspar is much darker on either side of these cracks. Secondary: Leucoxene and part of the riebeckite.

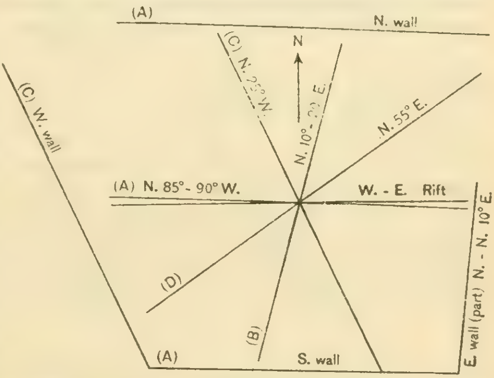

FIGURE 78.—Structure at Reinhalter quarry, West Quincy, Mass.

The "medium" of this quarry is a dark, very slightly greenish-gray stone of the same texture. Its shade is like the "medium" of the Hardwick quarry (p. 324), but its tint is different. It is darker than the "dark" of the Dell Hitchcock quarry but differs from that also in tint.

The quarry, opened before 1871, measures 200 by 150 feet on one side and 200 feet on the other and 250 feet in depth.

Rock structure: The sheets, 14 inches to 20 feet thick, extend down 250 feet from the rock surface. At a point on the east side, 150 feet down, they dip east. On the south side, 175 feet down, they strike N. 85° W. and dip 25°–35° S. Below that there is a sheet 55 feet thick. Joint and rift courses are shown in figure 78. Joints (A) dip 90°, form the north and south walls, and recur at intervals of 10 and 35 feet. At 35 feet from the north wall they form a 10-foot heading which extends from a point 100 feet below the surface to the bottom. Joints (B) are vertical, form the east wall, are intermittent, and are spaced 30 and 60 to 70 feet. The east wall is intersected by a wide heading striking N. 20° E. and dipping steeply east. Joints (C) dip 90° and form the west wall.

Joints (D) are vertical and exceptional. In about the center of the top of the north wall is a 25-foot heading, which at a point 50 feet down disappears behind it. The heading (A) has "dark" and "medium" granite on its south side and "extra dark" on its north side. The sheets at a point 175 feet down are intersected by several convex southward-curving partings, "toenails." The rift is reported as 90° below, but not quite 90° near the surface, and the grain as horizontal. Black knots are usually but a few inches in diameter, but some 2 feet by 1 foot 6 inches are reported. Gray knots are from 0.5 to 8 inches. Rusty stain measures up to 3 inches on joint faces, but down to 0.5 inch on sheet faces near the bottom.

Transportation, by a siding at the quarry, by cart one-fourth mile to cutting shed, and a shorter distance from shed to railroad.

The product consists of "extra dark," "dark," and "medium," but most of it is "extra dark." It is used for monuments and columns. The largest block obtained weighed 50 tons.

The **Swingle quarry** is about 600 feet southwest of West Quincy station and adjoins the Reinhalter quarry on the west. (See map, Pl. XXIV, No. 3.) Operator, J. S. Swingle, Quincy.

The granite (specimen D, XXVIII, 72, a), "extra dark," is a riebeckite-aegirite granite of very dark bluish-gray color and of medium to coarse, even-grained texture, with feldspars up to 0.5 inch and black silicates up to 0.3 inch. Its constituents are like those of the stone in the adjacent Reinhalter quarry (specimen 78, a).

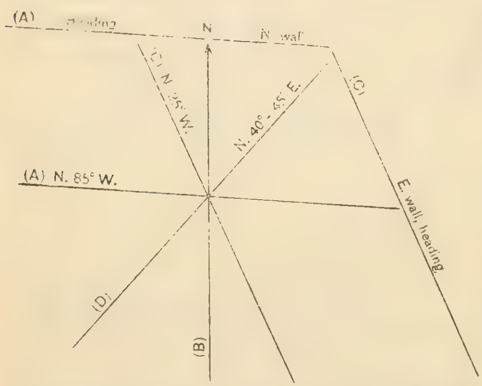

FIGURE 79.—Structure at Swingle quarry, West Quincy, Mass.

The contrast in the polished stone is confined to that between the black silicates and the dark gray of the other minerals.

An estimate of the mineral percentages in specimen 72, a, by the Rosiwal method, with a mesh of 0.5 inch and a total linear length of 20 inches, yields these results: Feldspars, 56; quartz, 33.50; riebeckite and aegirite, 10.50.

The quarry, opened about 1846, measures about 200 feet from north to south, by 175 feet across and 250 feet in depth.

Rock structure: Irregular horizontal sheets are apparent only to a depth of 100 feet, below which joints and headings predominate. This is a boulder quarry and its management is difficult. Joint and rift courses are shown in figure 79. (A), vertical or dip 75° S., form a heading on the north wall and are spaced 10 to 30 feet. (C), vertical, form a heading on the east, 30 feet wide, which separates this from the Reinhalter quarry. (D), diagonal, form a heading on the west wall dipping 75° SE. and another extending from east to south wall. They are spaced 2 to 10 feet and some dip 90°. (B), also diagonal, dip 70° E., form a heading intersecting the south wall and another at the northwest corner. The rift is reported as vertical with a north-south course west of heading (C), but with an east-west course east of it. This anomaly may be due to faulting. Knots, green or black, are reported as measuring from 6 inches to 2 feet in diameter. Rusty stain is from 0.5 to 2 inches thick on sheet surfaces at the bottom.

Transportation, by railroad siding for out of town shipments but by cart about 1 mile to local dealers.

The product is used mostly for monuments. Shipments have been made to Connecticut, Rhode Island, New Hampshire, Maine, New York, New Jersey, Pennsylvania, Delaware, Ohio, Indiana, Illinois, Michigan, Wisconsin, and Missouri. The usual maximum size of blocks quarried is 150 cubic feet, but blocks 40 by 6 by 8 feet are obtainable.

The **Berry quarry** has also been operated by J. S. Swingle since 1914.

The **Granite Railway quarry** derives its name from a primitive railroad constructed in 1826 to bring the granite for the Bunker Hill Monument from a neighboring opening to tidewater at Neponset River. The quarry now worked is about 1,050 feet west-southwest of West Quincy station. (See map, Pl. XXIV, No. 4.) Operator, Granite Railway Co., Quincy.

The granite (specimens, D, XXVIII, 68, b, h), "Quincy dark-blue railway," is a riebeckite-aegirite granite of dark bluish-gray color and medium to coarse, even-grained texture, with feldspars up to 0.5 inch and black silicates up to 0.3 inch. Its constituents, in descending order of abundance, are a dark bluish to greenish gray, black-streaked potash feldspar (orthoclase), in twins, minutely intergrown with soda-lime feldspar, apparently darkened by microscopic black particles and also somewhat kaolinized, containing blue-brownish crystals of riebeckite down to 0.009 millimeter long, also irregular particles of green aegirite and some slender ones up to 0.37 millimeter long arranged either along the twinning plane or the plane of intergrowth with the soda-lime feldspar; the black streaks are due to clusters of radiating fibrous crystals of a brown hornblende; smoky quartz with intersecting streaks or sheets of cavities, from less than 0.0028 to 0.0085 millimeter, also with aboundant microscopic black particles; blue-black riebeckite and green-black aegirite, largely intergrown; basal sections of the aegirite appear corroded; separate soda-lime feldspar (albite to oligoclase-albite) in very small amount. Accessory: Ilmenite, zircon in doubly terminated pyramids, apatite. Secondary: Kaolin, leucoxene, hematite and limonite stain (rare), brown hornblende, and, as shown by test, calcite.

The contrast between the smoky shade of the quartz and the slightly bluish to greenish gray of the feldspar is small. It lies mainly between these and the black silicates.

An estimate of the mineral percentages by the Rosiwal method yields the following results, with a mesh of 0.4 inch and a total linear length of 71.2 inches: Feldspars, 58.79; quartz, 33.74; riebeckite and aegirite, 7.47. Of course the last figure does not include the microscopic particles of the two black silicates.

E. C. Sullivan, a chemist of this Survey, extracted 0.13 per cent of CaO (lime) from this granite by means of hot dilute acetic acid, which indicates the presence of 0.25 per pent of $CaCO_3$ (calcium carbonate, calcite).

The "extra dark" of the same quarry (specimen D, XXVIII, 68, c) is darker than 68, b, but a trifle lighter than the "extra dark" of the Swingle quarry. The feldspar seems to be darkened by more brown hornblende and more abundant other black particles. There is also a dark orange-colored hornblende. The minute riebeckite crystals and long, slender aegirite particles are both arranged with reference to the twinning of the feldspars. An aegirite particle (0.2 by 0.14 millimeter) coated with radiating crystals of riebeckite (up to 0.09 millimeter long) occurs within a quartz area. Purple fluorite is mingled with the reibeckite.

The quarry, opened in 1826, is roughly T-shaped, the top of the T measuring about 800 feet N. 75° W. by 450 feet N. 10° E. and the stem being about

250 by 20 feet. Its depth ranged in 1906 from 50 to 70 feet, but 30 feet of rock had been removed from the present edge of the quarry. In 1906 a mass about 100 feet square, rising 30 to 40 feet above the edge and devoid of sheet structure, projected into the quarry west of the stem of the T.

Rock structure: A 15-foot diabase dike dipping 60° NNE., with a greenish rim a foot thick on its underside, bounds the quarry on the southwest. (See p. 52.) The granite under the dike has three sets of joints, one dipping about 50° in the opposite direction, one parallel to the dike, and a third striking N. 22° E. with the dip of the dike. In places the sheets are regular, in other places they are short lenses, and in others they are altogether absent. This is a boulder quarry. The courses of dike, joints, and rift are shown in figure 80. Joints (A), dip 55° SW., form a heading on the northeast, and are spaced 1 to 12 feet; (B), vertical, form the east and west walls and are spaced irregularly up to 300 feet; (C), diagonal and dipping 70° W., form a heading at the west angle of the T in the projecting mass; (D), diagonal, dip about 55° E., coated with riebeckite and hence called "black seams" (see p. 82), occur intermittently on the south side of the quarry. The rift is reported as vertical, with a N. 80° W. course, and the grain as also vertical at right angles to it, but feeble.

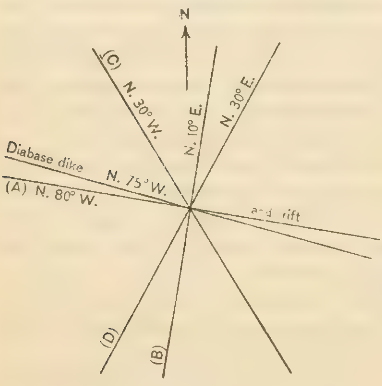

FIGURE 80.—Structure at Granite Railway quarry, West Quincy, Mass.

In the western part of the top of the T there is a mass of hematitic and chloritic granite ("oreï") extending 30 feet down from the surface. This is described fully on page 78. Knots of dark-gray shade measure up to 12 by 6 inches. Rusty stain is from 3 to 12 inches thick on joint and sheet faces in the deeper part of the quarry.

This company operates another quarry, opened in 1905, known as No. 4, Nos. 1, 2, and 3 be ng designations of parts of the last quarry. No. 4 lies west of the Swingle quarry and measured in 1906 about 200 feet N. 15° E. by 75 to 100 feet east and is from 15 to 40 deep. The sheets, 6 inches to 8 feet thick, are horizontal or dip north with the hill surface. The Bunker Hill quarry, which furnished stone for the Bunker Hill Monument, lies about 1,800 feet south of No. 4, but is now idle. (See map, Pl. XXIII.)

Transportation, by siding to New York, New Haven & Hartford Railroad.

The product is used mostly for monuments and polished building fronts. Specimens: Bunker Hill Monument; a polished monument 23 feet high to W. C. Whitney, former Secretary of the Navy, at Woodlawn Cemetery, New York. The waste is used for cellar stone, riprap, and paving.

The **Lepage quarry** is between the Granite Railway and the Cashman quarries. (See map, Pl. XXIV, No. 5.) It has now been abandoned.

The granite (specimen D, XXVII, 76, a), "extra light," is a riebeckite-aegirite granite of light pea-greenish color and medium to coarse, even-grained texture, with feldspars up to 0.5 inch and black silicates to 0.4 inch. Its constituents, in descending order of abundance, are a light pea-green potash feldspar (orthoclase, mostly twinned), minutely intergrown with soda-lime feldspar, somewhat kaolinized and contains more fine grains of aegirite than the gray granites of the region, but contains far fewer minute crystals of riebeckite; the aegirite is likely to be parallel to the twinning plane of the orthoclase or the plane of intergrowth of the two feldspars; amethystine

quartz, showing effects of strain and containing intersecting streaks and sheets of cavities, also minute black particles; blue-black riebeckite and green-black aegirite, in places intergrown; soda-lime feldspar (albite to oligoclase-albite). Accessory: Zircon, pyrite, fluorite. Secondary: Kaolin, carbonate, limonite, slender crystals of orange-yellow hornblende radiating from aegirite particles.

As pointed out on page 77, the peculiar color of this granite and its feldspar seems to be due to the abundance of fine grains of aegirite and to the absence or alteration of the minute riebeckite crystals. Kaolinization has also lightened its color. Blocks of the pea-green stone bordered by bright yellowish-brown stain afford striking contrasts (specimen D, XXVIII, 76, b). It takes a poor polish and is used only for bridges, curbing, paving, etc. On the north side of the quarry there is some "dark" adapted to monumental work.

The quarry, opened in 1905, measured in 1906 about 100 feet north to south by 60 to 80 feet across and from 30 to 45 feet deep.

Rock structure: The sheets, 1 to 5 feet thick, dip 10° S. Joints (a), strike N. 80°–85° W., dip 70°–80° N., form the south wall, spaced 4 to 10 feet; (b), strike N. 15° W., dip 90° and 70° E., form the west wall and a heading on the east wall, spaced 3 to 10 feet. The rift is reported as 90°, with an east-west course, and the grain as vertical, north-south.

The **Cashman quarry** is about 1,800 feet west of the West Quincy station. (See map, Pl. XXIV, No. 6.) It is now abandoned.

The granite, "extra dark," "medium," and "extra light," is a riebeckite-aegirite granite of very dark or medium bluish-gray or of light pea-greenish color, and of medium to coarse, even-grained texture. Its constituents correspond to those of the several varieties of Quincy granite as described on pages 77, 319.

The quarry, opened about 1876, is of irregular area owing to several offsets or projecting parts on the north, east, and west sides. It was in 1906, roughly, about 350 feet north to south by 225 feet across and from 70 to 100 feet deep.

Rock structure: The sheets, 1 to 5 feet thick, are lenticular and flat on the south side, but dip north at the north. Joints (a) strike about east, dip steep north or south, form a heading on the north side, and are spaced 10 to 75 feet. Joints (b) strike about north, dip 90°, form headings on east side and 35 feet west of it, and are spaced 10 to 30 feet. The rift was reported as vertical, about east-west, but in places steep north or south. When split from the side, the rift in those places is vertical. The grain is said to dip steeply, with north-south course. A workman stated that the rift in the "extra light" was superior to that in the dark stone, and the blocks in sight showed smooth rift breaks. The "extra light" occurs at both north and south ends of the quarry, and the dark in the center. Near a heading at southeast corner the granite is hematitic ("oreï"). (See p. 78.) Rusty stain is from 1 to 3 inches thick on both light and dark stone.

Transportation, by cart 2 miles.

The product is monumental and bridge work. Specimen structures: Arch bridge across Furnace Brook Parkway, West Quincy; five bridges between South Braintree and Whitman, on the Plymouth division of the New York, New Haven & Hartford Railroad.

The **Savo quarry** is about four-fifths mile west-northwest of West Quincy station. (See map, Pl. XXIV, No. 8.) It is now abandoned.

The granite (specimen D, XXIX, 84, a) is an altered riebeckite-aegirite granite of pinkish medium-gray color and medium to coarse, even-grained texture, with feldspars up to 0.5 inch and greenish silicates up to 0.2 inch. Its constituents are, in descending order of abundance, light-pinkish, not transparent potash feldspar (orthoclase), twinned, with minutely intergrown soda-

lime feldspar, considerably kaolinized but containing no riebeckite; its pinkish color must be attributed to hematite, arising either from the oxidation of FeO in the feldspar or of magnetite in the other particles; smoky quartz with intersecting streaks or sheets of cavities and minute black particles; riebeckite and aegirite altered to quartz, magnetite, carbonate, epidote and in some cases chlorite; a little soda-lime feldspar (oligoclase-andesine). Accessory: Zircon (rather large), fluorite. Secondary: Kaolin, carbonate, magnetite (some in crystals), chlorite, hematite. (See further on this granite p. 78.) The pink tint fades somewhat on exposure.

The quarry, opened in 1905, measured then about 135 feet N. 55° W. by 50 feet across and 40 feet in depth.

Rock structure: The sheets, 1 to 8 feet thick, dip 45° N. 25° E. Joints (a) strike N. 70° W., dip about 60° N. 20° E. and S. 20° W.; (c) strike N. 30° W., dip 90° and steeply west. The pink granite occupies the south half of the quarry and the pea-green the north half. The rift is reported as vertical, north-south, and the grain as horizontal. Rusty stain is 8 to 12 inches thick.

Transportation, by cart 1½ miles to West Quincy.

The **Gold-leaf quarry** is 4,500 feet N. 80° W. of the West Quincy station. (See map, Pl. XXIV, No. 7.) Operator, Quincy Quarries Co., Quincy. Quarry not operated in 1917–18.

The granite (specimens D, XXVIII, 71, a, b), "gold-leaf Quincy," is a riebeckite-aegirite granite of medium bluish green-gray color (a trifle lighter than 67, c, the "light" of Dell Hitchcock quarry), speckled with black and yellow-brown. Its texture is medium to coarse, even-grained, with feldspars up to 0.5 inch, black silicates to 0.3 inch, and yellow-brown stains to 0.5 inch, but the quartz areas are finely granular. Its constitutents, in descending order of abundance, are medium bluish green-gray potash feldspar (orthoclase), twinned, minutely intergrown with soda-lime feldspar, in places granulated, somewhat kaolinized, and containing many minute crystals of riebeckite and fine grains of aegirite, to both of which the feldspar owes its peculiar color; quartz, clear to light smoky, almost without cavaties, all granulated in particles mostly under 1 millimeter, rarely 2 millimeters in diameter; blue-black riebeckite and green-black aegirite, in places associated with limonite (and hematite?); soda-lime feldspar (albite and probably oligoclase-albite) in small amount. Fluorite is accessory. Secondary limonite occurs in irregular areas, mostly not related to the particles of black silicate, and this produces the yellow-brown stains.

An estimate of the mineral percentages by the Rosiwal method, with a mesh of 0.5 inch and a total linear length of 74 inches, yields these figures: Feldspars, 67.37; quartz, 23.01; riebeckite and aegirite, 9.62. As compared with the percentages in other Quincy granites these approximate those of the Wigwam quarry stone. This is the lightest of the Quincy monumental granites. The contrasts between the light bluish-green of the feldspar and the black particles and the yellow-brown stains are marked. The minute particles of granulated quartz reflect the light and, as it were, spangle the surface, and where the limonite stain coincides with the quartz areas the yellow-brown spots are the more conspicuous, hence the trade name "gold-leaf." It takes a high polish, but as small pits are likely to appear in the quartz owing to the dropping out of minute quartz particles, it seems better adapted to indoor ornamentation.

The quarry in 1906 was about 125 feet square and from 20 to over 50 feet in depth.

Rock structure: Joints (a) strike N. 80° W., dip vertical and steeply north, form the north wall, spaced about 50 feet; (c) strike N. 10° W., dip 30° E.,

form three headings in the east half and are spaced 4 to 15 feet. These apparently serve as sheets. Fine-grained gray knots of group 1 (p. 59) are 6 inches in diameter.

Transportation, by sidings connected with Granite branch of New York, New Haven & Hartford Railroad, as shown in Plate XXIV.

Product: The last building of any importance made from this stone is that of the Carnegie Institute at Pittsburgh, Pa.

The **Rogers quarry** is at the north foot of the Blue Hills, 1,500 feet northwest of West Quincy station, on Willard Street. (See map. Pl. XXIV, No. 9.) Operator, Quincy Quarries Co., Quincy.

The granite (specimen D, XXVIII, 70, d), "extra dark," is a riebeckite-aegirite granite of very dark purplish-gray color and of medium to coarse texture, with feldspars up to 0.5 inch and black silicates up to 0.3 inch. Its constituents are like those of the Reinhalter and the Granite Railway "extra dark" granite, described on pages 327, 329. The feldspars have more whitish kaolinized streaks, hence the general shade is slightly lighter than that of the granites referred to (78, a, and 68, c), and minute hematitic stains account for its more purplish hue. This quarry also yields the "dark."

The quarry, opened in 1832, measured in 1906 about 600 feet from north to south by 175 feet across and from 40 to 150 feet in depth.

Rock structure: The sheets are short and thick lenses, which render the structure obscure and irregular. (The structure is given in fig. 12 of U. S. Geol. Survey Bull. 354, 1908.) Joints (A) dip 90° or steeply north and are spaced 10 to 20 feet. (B) dip steeply east, form headings on east and west walls, and are spaced 10 to 20 feet. (C) dip 50° E., form a heading at the northwest corner, the faces of which are coated with riebeckite, and are spaced 6 inches to 4 feet. (See on these black joints, p. 82.) This heading intersects a heading of (B). (D), diagonal, dip 40° S. 45° W., are spaced 2 to 20 feet. At the south end several faces dipping 30°–60° N. may belong to (A).

The rift is reported as vertical, with east-west course, and the grain as also vertical, at right angles, but feeble.

A basic dike, 2 feet thick, at the north end dips 65° N. Fine-grained aplitic knots probably of group 1 (p. 59) occur. The largest reported was 3 by 1½ feet. Rusty stain is 1 to 12 inches thick. In places all the granite to a depth of 30 feet is somewhat stained, but in others good stone occurs at the top. At the south end, west side, the granite upon exposure discolors readily to a medium, slightly olive-gray. Specimen D, XXVIII, 70, b, describe on page 78, had been exposed three years at a point 30 feet down. In thin section the stain is seen to proceed from particles of riebeckite and aegirite.

Transportation, by siding from New York, New Haven & Hartford Railroad.

The product is used for monuments and the waste for road material, etc.

The **Mount Pleasant quarry** is at the northwest foot of the Blue Hills, in Milton Township, on Lyman Road, off Pleasant Street. (See map, Pl. XXIV, No. 11.) The quarry was operated in 1906, but is now abandoned.

The granite (specimen D, XXIX, 85, a), "dark Quincy," is a riebeckite-aegirite granite of dark bluish-gray color, a trifle lighter than 68, b ("dark-blue railway") and with a more bluish tinge. Its texture is medium to coarse, even-grained, with feldspars up to 0.5 inch and black silicates to 0.3 inch. Its constituents, in descending order of abundance, are a medium to dark bluish-gray potash feldspar (orthoclase, mostly twinned), minutely intergrown with soda-lime feldspar, in places somewhat kaolinized, with unusually abundant minute crystals of riebeckite and some particles of aegirite, also minute orange-colored hornblende crystals; quartz, dark smoky, with very slight bluish tinge, containing minute cavities and black particles in intersecting streaks

and sheets; blue-black riebeckite and green-black aegirite, in part intergrown; soda-lime feldspar (albite and probably oligoclase-albite) in very small amount. Accessory: Fluorite, allanite. Secondary: Kaolin, calcite, limonite, and probably the orange-colored hornblende.

The blueness of this stone is clearly due to the abundant riebeckite crystals in the feldspars. This comes out on the polished face. (See specimen 88, a, which is identical but from the adjoining quarry, described below.)

George Steiger, chemist, of this Survey, extracted from this granite by means of hot dilute acetic acid 0.15 per cent of CaO (lime), which indicates a content of 0.26 per cent of $CaCO_3$ (calcite). Thin sections also show calcite.

The quarry, opened in 1901, measured in 1906 about 125 by 100 feet and 100 feet in depth.

Rock structure: The sheets, 5 to 27 feet thick, are horizontal and turn to dip gently east. Some of the sheet surfaces on the west side are coated with riebeckite. (See p. 82.) Joints (b), strike N. 10° E., dip 90° and steeply east, form the east wall, spaced 5 to 11 feet; (a), strike N. 60° W., form a heading on the south side, spaced 2 to 15 feet; (ϱ), diagonal, strike about northwest, form a heading near the west wall, which has a dark-bluish stone northeast of it but inferior light stone southwest of it. Black riebeckite-coated joint and sheet faces abound in this part. The rift is reported as vertical, with a nearly N. 10° E. course. Rusty stain is up to 2 inches thick on the lower sheets.

Transportation, by cart 2¼ miles to railroad at West Quincy or 3 miles to cutting sheds at Quincy.

The chief product was used for monuments.

The **Maguire & O'Heron quarry** is at the northwest foot of the Blue Hills, in Milton Township, about 800 feet southwest of the Mount Pleasant quarry, off Pleasant Street. (See map, Pl. XXIV, No. 10.) The quarry was operated in 1906, but is now abandoned.

The granite (specimen D, XXIX, 88, a), "dark Quincy," is a riebeckite-aegirite granite of dark bluish-gray color like that of the adjoining Mount Pleasant quarry (specimen 85, a). Its texture and constituents are also identical.

The polished face brings out the marked bluish tinge of the feldspars, which are streaked with whitish kaolinized parts and contrast somewhat with the smoky quartz, but much more with the black silicates. This stone differs from the "dark-blue railway" (specimen D, XXVIII, 68, h, p. 329) by its slightly more bluish tinge, which is due to the greater abundance of microscopic riebeckite crystals in the feldspars.

An estimate of the mineral percentages by the Rosiwal method, with a mesh of 0.5 inch and a total linear length of 20 inches, yields these figures: Feldspars, 55.80; quartz, 33.10; riebeckite and aegirite (excluding microscopic particles), 11.10.

The quarry, opened in a small way about 1882 but in a larger way in 1901, measured in 1906 about 250 feet N. 35° E. by 75 to 150 feet across and 70 feet in depth.

Rock structure: The sheets, 3 to 15 feet thick, dip up to 20° SW. Joints (b), strike north, dip steeply east, form a 50-foot heading on the southwest wall, spaced 3 to 20 feet; (c), strike N. 20°–25° W., dip 75° ENE., form a heading in the middle of the south end; (d), strike N. 35° E., dip 90° to steep west, form the east and west walls, spaced 3 to 100 feet. The rift is reported as nearly vertical, with a north strike, and the grain as horizontal. Quartz veins, 1 to 3 inches thick, dipping 30° SE. and inclosed in belts of whitish discoloration, recur at intervals of 3 to 18 feet. (See pp. 325–326.) Rusty stain 3 to 18 inches thick on the lower sheets.

The product was used mostly for monuments and the waste for cellar stone. Specimen monuments: Bradley monument, Purdy Station, N. Y.; monument to Samuel Neilson, at Poughkeepsie, N. Y.; Long monument at Mansfield, Ohio; Patterson monument at Ashland, Pa.; Meehan monument at St. Joseph's Cemetery, Boston; and Mead Chapel, Lake Waccabuc, N. Y.

The **Sartori quarry** is on Pine Hill, on the southeast side of the Blue Hills, in Quincy Township, close to the Braintree line. (See map, Pl. XXIV, No. 12.) It is now abandoned.

The granite (specimen D, XXIX, 82, a) is an altered riebeckite-aegirite granite of very dark, dull greenish to brownish gray color, almost without contrasts, and of medium to coarse, even-grained texture, with feldspars up to 0.5 inch and altered black silicates up to 0.3 inch. Its constituents, in descending order of abundance, are a dark greenish to brownish gray, nearly opaque potash feldspar (orthoclase), twinned, some of which is minutely intergrown with soda-lime feldspar, mostly much kaolinized and in places much micacized, and here and there stained with hematite (no aegirite or riebeckite crystals were detected in it); smoky quartz, in places pinkish from hematite stain, with intersecting streaks or sheets of cavities and minute black particles; riebeckite and aegirite particles completely altered to masses of greenish biotite, magnetite (mostly octahedral), carbonate, and quartz with some chlorite or delessite; very little soda-lime feldspar (oligoclase). Accessory: Magnetite, zircon, allanite, fluorite. There are also brownish balls (spherulites) of radiating fibrous crystals, 0.02 to 0.1 millimeter in diameter, some of which polarize like zircon. Secondary: Biotite, a white mica, carbonate, chlorite or delessite, hematite, magnetite.

This granite differs by its greenish-brownish color from all the other Quincy granites, although microscopically it approaches the pinkish of the Savo quarry (p. 331), but it differs from that by the different alterations of its feldspars and black silicates.

The quarry measured in 1906 50 by 30 feet and 15 to 20 feet in depth.

The product had been found adapted only to bases, curbing, and paving.

The **Stacy quarry** is in Braintree Township just beyond the Quincy line, about a mile south of Quincy station. Operator, J. Stacy, South Quincy.

The granite (specimen D, XXXVIII, 23, a), "red Braintree," is (probably) an altered riebeckite-aegirite granite. It is of dull medium reddish-gray color with weak contrasts and of coarse, even-grained texture, with feldspars up to 0.5 inch. Its constituents, in descending order of abundance, are dull pinkish medium-gray orthoclase and microperthite, much kaolinized; medium smoky quartz with fluidal cavities; and very little plagioclase. No other silicates detected (riebeckite and aegirite probably decomposed). Accessory: Magnetite in cubes and octahedra, pyrite. Secondary: Kaolin, carbonate, hematite, limonite stain.

The quarry was opened in 1915 and is small.

The product is used for monuments.

PLYMOUTH COUNTY.

The granites of Plymouth County cover very small areas and are not shown on the geologic map of the State in Bulletin 597.

BROCKTON.

The **Brockton Heights quarry** was on Pearl Street, Brockton Heights, about 2½ miles west of Brockton station in the same township. (See Dedham topographic map, U. S. Geol. Survey.)

This quarry was abandoned in 1914 and the property cut up into house lots. The granite is described because of its exceptional character.

The granite (specimen D, XXX, 130, a), is a biotite-hornblende (or altered augite-hornblende) granite of light greenish-gray color with large pink spots and matrix of medium texture (feldspars up to 0.3 inch and mica up to 0.2 inch) and with porphyritic light-pink feldspars up to 0.8 inch. The constituents of the matrix, in descending order of abundance, are milk-white to greenish soda feldspar (albite), much micacized; clear colorless to slightly milky quartz with cavities in sheets; chlorite, probably after biotite (possibly after augite); a little microperthite (potash feldspar, microcline, minutely intergrown with soda feldspar, albite, kaolinized, with epidote and zoisite in microscopic particles); and yellow hornblende in fibrous radiating crystals. The large pink crystals are also microperthite and contain sparse groups of yellow hornblende crystals. Accessory: Magnetite, titanite. Secondary: Epidote, zoisite, plentiful carbonate, chlorite, a white mica, kaolin, quartz. There are veinlets of carbonate, epidote, and quartz. Effervesces with muriatic-acid test.

Sheet and joint structure were found to be defective, and there was no perceptible rift or grain.

Specimen of product: Mattapan station on New York, New Haven & Hartford Railroad.

HINGHAM.

The **Hingham seam-face quarries** are in Hingham Township, 3½ miles S. 15° W. of Hingham station and about three-fourths mile southeast of Lovell Corners. (See Abington topographic map, U. S. Geol. Survey and Pl. XXIII.) Operator, Plymouth Quarries, Inc., 6 Beacon Street, Boston.

The granite (specimens D, XXX, 124, a, b), "Hingham," is an aplite of light, slightly greenish-gray color and of fine, slightly porphyritic texture, with feldspars up to 0.2 inch. Its constituents, in descending order of abundance, are milk-white soda-lime feldspar (oligoclase-albite), much kaolinized and micacized and a little epidotized, the alteration proceeding from within the crystals outward; clear colorless quartz, with cavities, rare particles of smoky quartz up to 0.1 inch; pale-greenish potash feldspar (microline), a little kaolinized; very little biotite, and more of chlorite after biotite, both in small particles and sparse. Accessory: Pyrite, plentiful, and magnetite. Secondary: Kaolin, a white mica, chlorite, and epidote, mostly about the chlorite. No effervescence with muriatic-acid test.

The following analysis of the fresh aplite made in 1900 by F. J. Moore and given in a report made to the company by W. O. Crosby and G. F. Loughlin is published here for reference:

Analysis of aplite from Hingham, Mass.

Silica (SiO_2)	74.06
Alumina (Al_2O_3)	14.45
Ferrous oxide (FeO)	1.44
Ferric oxide (Fe_2O_3)	.15
Potash (K_2O)	4.36
Soda (Na_2O)	4.74
Lime (CaO)	1.03
Magnesia (MgO)	Trace.
Sulphur (S)	.02
Water (loss on ignition)	.52
	100.77

The 0.02 per cent of sulphur is equivalent to about 0.04 per cent of pyrite. Traces of manganese and phosphoric acid were noted.

The same report gives the following additional determinations made by A. A. Blanchard in 1910:

Water below 110° C	0.041
Water above 110° C	.456
Carbon dioxide (CO_2)	.013
Total pyrite (FeS_2)	.10
Material soluble in water	.08
Material soluble in carbonic acid	.13

Tests made at the Watertown Arsenal in 1910 on specimens of the fresh aplite show a crushing strength ranging from 32,900 to 39,800 pounds to the square inch. Tests of the transverse breaking strength of the fresh aplite made for the company by Crosby and Loughlin gave these results:

Results of tests of breaking strength of aplite from Hingham, Mass.

Number of tests.	Size of beams (inches).	Span (inches).	Maximum load (pounds).	Transverse breaking strength (pounds per square inch).
4	3 by 6	12	10,090-22,310	3,320-3,770
4	4 by 8	12	20,610-49,420	2,950-3,470
2	4 by 8	19	16,820-17,700	3,400-3,660
General average				3,440

In comparison with these results two Watertown Arsenal tests of "Rockport granite," 4 by 8 inch beams and 19-inch span, show transverse breaking strengths of 2,404 to 2,416 pounds; and one of Milford (Mass.) granite, 1,745 pounds.

Tests of porosity and absorption made for the company by Crosby and Loughlin on four 3-inch cubes of the rusty aplite show from 0.285 to 0.371 per cent, or 0.04 to 0.55 gram per square inch of surface. In these tests the cubes were first dried at 110° C. for 24 hours, weighed, soaked for 48 hours in distilled water, the first two hours in boiling water, and then weighed again after removing excess water. Similar tests with two 4-inch cubes of the fresh aplite, which, however, were soaked for six weeks instead of two days, showed only 0.0052 gram per square inch of surface.

The specific gravity of the fresh aplite was found by the same persons to be 2.637, which corresponds to a weight of 164.8 pounds to the cubic foot.

The quarries, begun many years ago for rough-faced stone but only in 1891 for seam-faced stone, comprise three openings. The largest (No. 1) was in 1910 150 feet square and 25 to 45 feet deep. No. 3, 600 feet S. 80° E. of No. 1, was 75 by 30 feet and 10 to 20 feet deep.

Rock structure: At the largest opening the sheets, very imperfectly developed and 4 inches to 6 feet thick, dip 5°–20° NW. There are five sets of joints—(*a*), vertical, strike N. 25° E., forms a wide heading with joint spaces 2 inches to 2 feet 6 inches; (*b*), strike N. 25° W., dip steep N. 65° E., spaced 10 to 30 feet; (*c*), strike N. 55° W., dip 70° N. 35° E., only two 2 feet apart; (*d*), strike N. 30° W., diagonal to quarry, dip steep S. 60° W., one only; (*e*), strike N. 77° W., dip steep N. 13° E., forms the north and south walls.

At opening No. 3 there are no sheets whatever. Joint (*a*) forms a heading with spacing 8 inches to 3 feet; (*b*) dips 75° S. 65° W. to 90° and is spaced 10 to 30 feet; (*c*) dips 40° S. 35° W.

All these sheet and joint faces are more or less stained with limonite from 0.06 to 2 inches thick, due to the oxidation of the somewhat plentiful pyrite. There are grayish knots up to 0.5 inch, rarely 2 by 10 inches.

Owing to the hardness of the granite, the scarcity of sheets, the superabundance of joints and headings, and the prevalence of "sap" these would be very discouraging quarries to work for ordinary purposes, but in supplying the demand for rusty seam-faced stone their petrographic and stuctural features are turned to good account. Blocks, 4 to 15 inches thick with a seam face, are used either as trimmings or for the main exterior, and the rough-faced unstained stone is used as trimmings. (See p. 293.) The following quotation concerns this phase of the granite industry: [48]

"To the ordinary uses to which granite is put there must be added the somewhat recent demand for the sap portions for decorative ashlar work and rustic masonry. The quarries which possess sap rock of the desirable colors are earning a new and adventitious revenue. In fact, the increasing demand for seam-faced granite and other rocks has led to the opening of several granite quarries which produce only stock of this kind. The demand for seam-face granite is steadily increasing; its introduction is becoming more general, and its artistic merits are wanting better appreciation."

Transportation, by cart 2 miles to East Weymouth station or 16 miles direct to Boston.

Product: The intersection of some of the joints and sheets makes it possible to obtain a regular supply of rusty seam-faced stones with angles 90° or 120°. The great crushing strength of this aplite has brought it into demand for keystone for tunnel arches.

It has been furthermore proposed to transform "headings" and "sap," the ordinary obstacles to granite quarrying, into "things of beauty" by carving bas-reliefs of leaves and garlands on the iron-stained joint faces. This is done by cutting away the rusty part, usually from 0.125 to 0.25 inch thick, so that the leaves in brown project on a light-grayish ground. Blocks thus worked can be utilized in ornamental bands on exteriors.

Specimen edifices: Harkness Memorial Quadrangle, Yale University, New Haven, Conn.; Bates College Chapel, Lewiston, Maine; First Baptist Church, Braintree, Mass.; State Armory, Adams, Mass; Faith Church, Springfield, Mass; W. O. Briggs residence, Detroit, Mich.; art building, Vassar College, Poughkeepsie, N. Y.; Trinity Church, Syracuse, N. Y.; B'Nai Jeshurun Synagogue, New York City; Church of the Covenant, Wilmington, N. C.; Calvary Episcopal Church, Providence, R. I.

The **Miller seam-face quarry** is in Hingham Township about 2¼ miles south-southeast of East Weymouth station and 1 mile east-southeast of Lovell Corners. (See Abington topographic map, U. S. Geol. Survey.) Operator, J. E. L. Miller, East Weymouth.

The granite (specimen D, XXX, 125 b), "Weymouth," is an aplite identical with that of the quarries last described and evidently belongs to the same mass. In thin section the biotite appears less altered to chlorite.

The quarry, opened in 1901, is triangular in area, 100 feet on two sides and 125 feet on the other, and in 1910 was 30 to 45 feet deep.

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[48] Whittle, C. L., The building and road stones of Massachusetts: Mineral Industry, vol. 7,, for 1898, New York and London, p. 638, 1899.

Rock structure: There are no sheets, but three sets of joints—(*a*), strike N. 25° E., forms headings with joint spaces of 2 inches to 3 feet; (*b*), vertical strike N. 25° W., spaced 10 to 25 feet; (*c*), strike N. 65° E., dip 40° S. 25° E. A diabase dike 18 inches thick strikes about east.

The product, used mostly for seam-faced work, is carted to East Weymouth. Specimens: Gateway, Albany Rural Cemetery; Congregational Church, Wollaston; Episcopal Churches, Hingham, Holyoke, and Brookline; Baptist Church, Brockton; Unitarian Church, Winchester; Methodist Episcopal Church, Dorchester, Mass.; city bridge, Waterbury, Conn.; Episcopal Church, Newport, R. I.

The **Hamilton Seam Face quarry**, recently opened, is in Hingham Township. Operator, Hamilton Seam Face Granite Co., 48 Cornhill, Boston.

Product, specimen edifices: St. Vincent Ferrer Church, Sixty-sixth Street and Lexington Avenue, New York City; Presbyterian Church, Greensburg, Pa.

SUFFOLK COUNTY.

REVERE.

The felsite porphyry of Revere is in an area designated "Mattapan volcanic complex (flows, tuffs, breccias, and dikes)" on the geologic map of the State in Bulletin 597, and these rocks are all regarded as of early Carboniferous age.

Although felsite porphyry is not a granite, it is a related igneous rock of almost identical chemical composition. The purplish-brown felsite porphyry of Black Ann Hill, in Revere, has been found to be very valuable for concrete construction. Tests made by the engineer of the Boston Transit Commission show that beams of 30-inch span, made with broken stone and the felsite dust from the crusher (presumably with ¼-inch screenings), have an average breaking strength 15.74 per cent higher than that of beams made with the same broken stone and sand. The superiority of felsite dust to sand for concrete is probably due to the fact that the angularity of the vitreous fragments is greater than that of water-rolled quartz and feldspar grains.

The **Black Ann Hill quarry** is at the southeast foot of Black Ann Hill, in North Revere, that part of Revere Township which lies between the townships of Malden and Saugus. (See Boston topographic map, U. S. Geol. Survey.) Operators, H. & D. Burnett, Franklin Park.

The rock (specimen D, XXXII, 13, a), "Revere," is a rhyolitic felsite porphyry [49] of very dark purplish-gray color and of dense, apparently homogeneous texture, with very minute whitish veins and close joint faces coated with films of calcite. It effervesces with muriatic-acid test. Under the microscope it shows a fluidal spherulitic banded texture, with porphyritic crystals of orthoclase (?), albite, and oligoclase; also particles of quartz and rare scales of biotite and chlorite. Accessory: Magnetite, zircon. Veinlets of quartz and carbonate fault the feldspars. Secondary: White micas, epidote, carbonate, quartz, chlorite.

The quarry has an east-west working face 75 to 100 feet high and 200 feet long.

A trap or diabase dike crosses the felsite, from east to west, tapering out.

Transportation, by cart one-fourth mile to siding on Saugus branch of Boston & Maine Railroad.

The product is used for roads and concrete material, and the ⅜-inch screenings and dust are sought for use in concrete in the place of sand. This quarry sup-

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[49] Determination by Whitman Cross, of the U. S. Geological Survey.

plied over 61,000 tons of crushed felsite for the construction of the East Boston tunnel and 21,000 tons to the United States Engineer Corps in 1898 for the construction of the battery at Fort Heath, in Winthrop. The dust was also used in 1908 in the concrete of two large schoolhouses, three fire-engine stations, two city stables, the hospital, and the armory in Chelsea.

H. A. Carson, chief engineer of the Boston Transit Commission, had the relative value of the dust of this felsite (with ⅝-inch screenings) and of sand, for concrete, tested in beams of 30-inch span, with these results:

Test of felsite dust and sand for concrete.[a]

	Average breaking strength.	Average modulus of rupture.
	Pounds.	
Beams with sand	3,347	666
Beams with felsite dust	3,874	783

[a] See Boston Transit Comm. Seventh Ann. Rept., A, p. 41, Cong. 15, 1901.

LYNN.

Although the **Sheehan quarry** is in the town of Lynn, in Essex County, it is in the same geologic area as the Black Ann Hill quarry and is therefore mentioned here. Operator, John W. Sheehan, 585 Western Avenue, Lynn.

The rock appears to be identical with the dark purplish rhyolitic felsite porphyry of the Black Ann Hill quarry.

It is crushed for concrete and roads and used in blocks for foundations.

WORCESTER COUNTY.

MILFORD GRANITE DISTRICT.

TOPOGRAPHY.

Milford lies 16½ miles southeast of the city of Worcester. (See map, Pl. XXIII.) It is a region of low hillocks with north-northeast and northwest trends. The situation of the quarries is shown in figure 81. They lie between N. 10° W. and N. 45° E. of Milford. Two are just over the line in Hopkinton (Middlesex County). All are between the 300 and 500 foot levels.

GEOLOGIC RELATIONS.

The granite of Milford has been described by Emerson and Perry,[51] and recently by Emerson,[52] who writes:

"The Milford granite occupies a large area extending from Westboro and Southboro, Mass., to Cranston, R. I., and a small area west of the principal one, chiefly in Grafton, Mass. * * * The Milford granite is intruded into the Northbridge granite gneiss and into the supposed Algonkian rocks and is overlain by the Carboniferous Bellingham conglomerate of the Woonsocket area.

[51] Emerson, B. K., and Perry, J. H., The green schists and associated granites and porphyries of Rhode Island: U. S. Geol. Survey Bull. 311, pl. 1, 1907.

[52] Emerson, B. K., Geology of Massachusetts and Rhode Island: U. S. Geol. Survey Bull. 597, pp. 165, 166, 1917.

So far as the formation itself is concerned, there seem to be no relations by which to determine its age more closely, but it is apparently of the same age as the Dedham granodiorite and it is therefore regarded as probably Devonian.

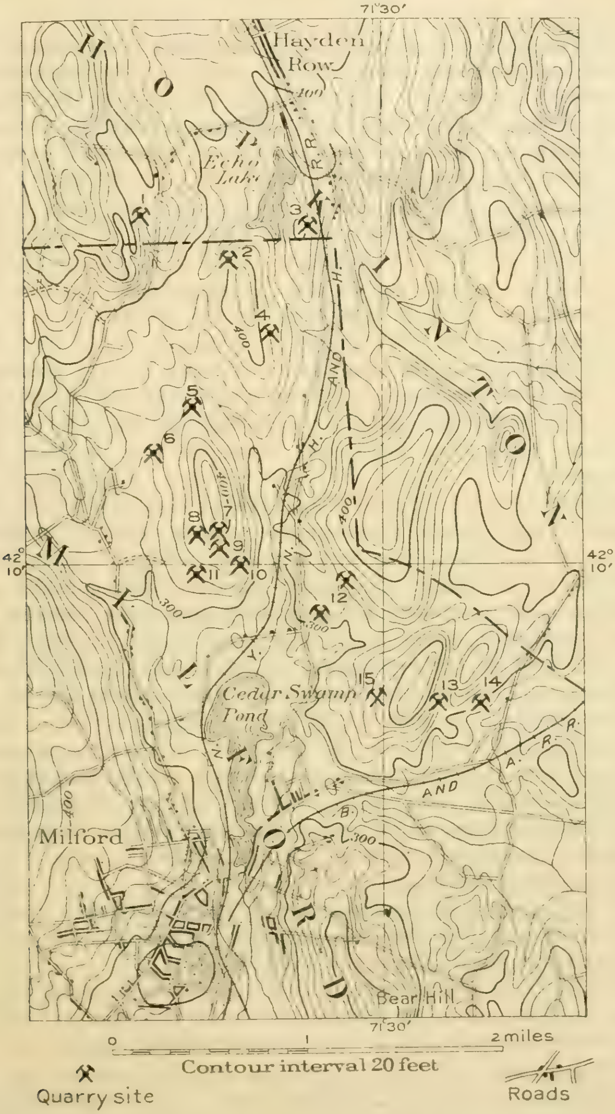

FIGURE 81.—Map of Milford, Mass., showing location of granite quarries. 1, Maguire; 2, Echo Lake; 3, Hopkinton; 4, Cutting; 5, Massachusetts Pink; 6, North Milford; 7, No. 8, Webb; 8, No. 7, Webb; 9, No. 5, Webb; 10, No. 3, Webb; 11, No. 4, Webb; 12, Bay State; 13, East; 14, Norcross; 15, No. 5, Webb. New Bay State quarry a little northeast of No. 12.

"There is generally around the granite a dark hornblendic border, supposed to be a contact phase of the granite magma, which is described below as the Ironstone quartz diorite."

On the map of Bulletin 597 the granite of this district appears under the designation "Milford granite (biotite granite with blue quartz)."

"MILFORD GRANITE."

The following epitomizes the descriptions of rough and polished specimens and thin sections of granite given beyond. Analyses and tests are also summarized. Milford granite is a biotite granite. Its general color ranges from a light gray or light pinkish-gray to a medium, slightly pinkish or pinkish and greenish-gray, but always with spots rich in black mica from 0.2 to 0.5 inch across and in some cases tapering out to an inch in length.

Its texture ranges from medium to coarse, not porphyritic; but, owing primarily to a marked flow structure and secondarily to compression, there is some alinement of particles, giving the stone a slightly gneissoid appearance. The feldspar, quartz, and biotite are each likely to form continuous lenticular areas up to an inch in length. On the polished face the quartz is seen to be finely granular. The general appearance of the stone varies according to the relation of the direction of the cut face to that of the flow structure. Wherever the plates of black mica, which lie with their major axes in the plane of the flow structure, coincide with the face of the stone, it will show much larger black spots than where the face intersects that plane at right angles.

Its constituent minerals, in descending order of abundance, are (1) a more or less delicate pink, rarely cream-colored potash feldspar (orthoclase and microcline), minutely intergrown with soda-lime feldspar and in places somewhat kaolinized; (2) faintly blue quartz fractured into particles up to 1.75 millimeters, in some specimens not over 0.75 millimeter, showing some arrangement of cavities in sheets and in places with hairlike crystals presumably of rutile; (3) a slight yellowish-green to milk-white, rarely clear striated soda-lime feldspar (albite to oligoclase-albite), which, where not clear, abounds in minute crystals and particles of epidote and zoisite, scales of white mica, and some chlorite and kaolin; (4) biotite (black mica), some of it chloritized and associated with epidote. Accessory: Garnet, pyrite, magnetite, ilmenite, zircon, allanite, (usually rimmed with epidote), apatite. Secondary: Kaolin, white mica, epidote, zoisite, calcite (usually in the soda-lime feldspars), titanite (about probable ilmenite in biotite), hematite. There is some radiate intergrowth of quartz and feldspar.

The color of the stone is governed mainly by its feldspars, pink from the potash and green from the soda-lime feldspar. These are but very slightly modified by the pale-bluish tinge of the quartz.

The somewhat gneissoid arrangement of the minerals, giving the feldspar and quartz particles uncertain boundaries in the direction of the flow, prevents the accurate application of the Rosiwal method, which provides that no one particle should be crossed more than once by lines parallel. A specimen from quarry No. 8 of the Webb Pink Granite Co., in which there is little if any flow structure, contained the following percentages: Feldspar, 55.91; quartz, 35.66; biotite, 8.43.

Five tests on three specimens of the more gneissoid granite showed the following ranges: Feldspar, 49.92-70.83; quartz 23.04-41.08; biotite, 4.72-11.29. These variations are due partly to the very different proportion of biotite on the different faces of the rock, as already explained.

Three analyses of this granite, made by L. P. Kinnicutt and R. H. Richards, are given under the respective quarries. They show these extremes:

Extremes of analysis of Milford granite.

Silica (SiO_2)	72.02–77.08
Alumina (Al_2O_3)	12.54–14.43
Iron oxide (FeO)	.52– .95
Iron sesquioxide (Fe_2O_3)	.00– 1.25
Manganese oxide (MnO)	.24– .33
Lime (CaO)	.75– 1.18
Magnesia (MgO)	Trace– .01
Potash (K_2O)	4.99– 5.41
Soda (Na_2O)	3.64– 5.85

The following analysis of the granite from one of the Norcross Bros.' quarries was made by Prof. C. F. Chandler, of Columbia University.[53]

Analysis of Milford granite.

Silica (SiO_2)	76.07
Alumina (Al_2O_3)	12.67
Iron sesquioxide (Fe_2O_3)	2.00
Manganese oxide (MnO)	.03
Lime (CaO)	.85
Magnesia (MgO)	.10
Potash (K_2O)	4.71
Soda (Na_2O)	3.37
	99.80

E. C. Sullivan, a chemist of this Survey, extracted, by means of hot dilute acetic acid, 0.06 per cent of CaO (lime) from an average specimen from the Cutting quarry. This lime was thus present in the form of $CaCO_3$ or calcite (calcium carbonate) to the extent of 0.107 per cent, its presence being shown in these sections. It probably was formed from the decomposition of the lime-soda feldspar.

Six crushing tests made at the United States Arsenal at Watertown, Mass., show an ultimate strength of 20,000 to 29,200 pounds to the square inch.

Those sections of the stone in which mica is least abundant take a good polish, but the others are not likely to preserve their polish in prolonged outdoor exposure. The scarcity of pyrite and magnetite on the polished face is very noticeable. Unfortunately the delicate pink of this granite after a few years' exposure becomes buff-colored, as may be observed in the Pennsylvania Railroad station in New York. This is very probably due to the passing of the hematite (Fe_2O_3) of the potash feldspar into limonite ($Fe_4O_9H_6$).

GEOLOGY OF MILFORD QUARRIES.

The diorite schist dikes that traverse this granite have already been described on page 56, and the probable connection between the development of schistosity in these dikes and the stress which granulated the quartz of the granite has been pointed out. There are also dikes of aplite from 0.5 inch to 4 feet thick, some of it a quartz monzonite in composition, and dikes of porphyritic granite with N. 10° and 35° E. and N. 20° W. courses. Some of these contain elliptical biotitic segregations (or inclusions?).

The flow structure strikes N. 10°, 35°, 40°, 45° W. and N. 77° E. and dips 40° E. to 90° or in places is nearly horizontal.

[53] Day, W. C., U. S. Geol. Survey Ann. Rept., pt. 6, continued, p. 221, 1898.

There are inclusions of biotite gneiss or mica diorite from a few inches to 2 feet thick, showing that this rock overlay or adjoined the granite at the time of its intrusion.

The rift is reported as everywhere horizontal and the grain as vertical with a N. 40° E. to an east-west direction. Rift and plane of flow structure are in places nearly parallel.

Sheets, 6 inches to 18 feet thick, are generally irregular or undulate horizontally with inclinations up to 20°.

As will be seen from the quarry diagrams, there is a wide range in the joint courses. They are north, N. 10°, 20°–25°, 45°, 50°, 60° E., and N. 60°, 70°, 80° W. Those occurring at the largest number of quarries are north to N. 10° E., N. 45°–60° E., and N. 55°–70° W. The filling of a parted joint with calcite probably derived from once overlying calcareous rocks has been noted on page 83.

QUARRIES.

The **Cutting quarry** is in Milford Township, 3 miles N. 5° E. of Milford and half a mile south of Echo Lake (fig. 81). Quarry idle.

The granite (specimens D, XXVIII, 13, a, b, c), "Milford pink" is a biotite granite of a very slightly pink-tinted light-gray color and conspicuous black spots. Its texture is somewhat gneissoid, medium to coarse, with particles up about 0.5 inch. In faces cut parallel to the plane of flow structure the black spots measure fully 0.5 inch, but when cut in the traverse direction about 0.3 inch. The quartz areas are always granular, the particles up to 1 millimeter in diameter and exceptionally 1.5 millimeters. The rock consists of the following minerals, in descending order of abundance: A very delicate pink potash feldspar (orthoclase and microcline, both with minutely intergrown soda-lime feldspar); quartz with minute cavities arranged in sheets, appearing colorless in isolated particles but in the aggregate having a very pale bluish tinge; a milk-white to pale-greenish striated lime-soda feldspar (albite to oligoclase-albite), usually crowded with particles and crystals of epidote and zoisite from 0.0094 to 0.076 millimeter in length; biotite (black mica), some of it altered to chlorite and associated with epidote. Both feldspars are somewhat kaolinized, particularly the soda lime. Accessory: Garnet, rare pyrite and magnetite, titanite, zircon, allanite crystals up to 1 millimeter long coated with epidote, apatite. Secondary: Kaolin, epidote, zoisite, chlorite, calcite, hematite.

An estimate of the mineral percentages with half-inch mesh and total linear length of 45.5 inches yields: Feldspars, 65.67; quartz, 23.04; biotite, 11.29.

The following analysis was made by Leonard P. Kinnicut, of the Worcester Polytechnic Institute, in 1898, and is given here for reference.

Analysis of granite from Cutting quarry, Milford, Mass.

Silica (SiO_2)	77.08
Alumina (Al_2O_3)	12.54
Iron oxide (FeO)	.95
Lime (CaO)	.75
Magnesia (MgO)	.01
Potash (K_2O)	4.99
Soda (Na_2O)	3.64
	99.96

E. C. Sullivan, a chemist of this Survey, extracted 0.06 per cent of CaO (lime) from this granite by hot dilute acetic acid. This indicates the pres-

ence of 0.107 per cent of $CaCO_3$ (calcium carbonate) or calcite, the presence of which is shown in thin sections.

Two tests made at the United States arsenal at Watertown, Mass., in 1898, give it an ultimate strength of 25,252 and 27,226 pounds to the square inch.

The quarry, opened before 1889, measured in 1906 about 500 feet in a north-northwest direction by 150 feet east-west and 20 to 30 feet in depth.

Rock structure: The sheets, 6 inches to 18 feet thick, are horizontal but irregular in places. The rift is reported as horizontal and the grain as vertical.

The peculiar mica diorite schist dike on the west side is described on page 56. Aplite dikes are 5 inches to 2 feet thick. The courses of joints, flow structure, dikes, and grain are shown in figure 82.

Heading (A) dips 70° E. and joint (B), only at the north end, dips 65° SSE. Bands of more biotitic granite with groups of black elliptical schistose knots or inclusions indicate the direction of flow. In this section these show particles all under 0.1 inch, mostly biotite, next a plagioclase much altered to epidote and zoisite, and lastly quartz. Garnets in roundish grains are also present. Rusty stain along the sheets is 6 to 12 inches thick.

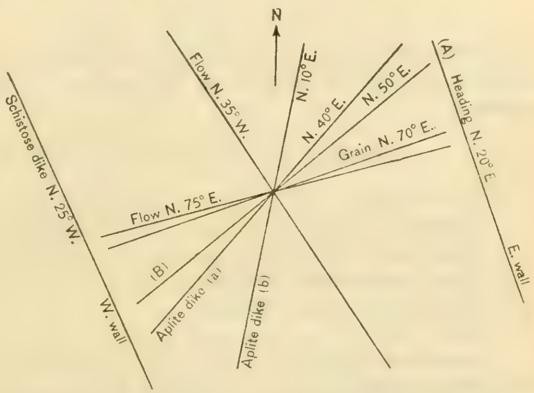

FIGURE 82.—Structure at Cutting quarry, Milford, Mass.

Transportation, by siding from the New York, New Haven & Hartford Railroad and track from quarry to cutting shed.

The product is used mainly for buildings. Specimen structures: Bank building, Newton, Mass.; street-railway depot at Georgetown, D. C.; New York State monument on Lookout Mountain, Chattanooga, Tenn., consisting of a shaft 6 feet in diameter and 50 feet high made in sections; part of the base and all the lantern for the Pennsylvania Railroad terminal station at New York.

The **East quarry** is in Milford Township, 1¾ miles northeast of Milford (fig. 81). Operator, Milford Pink-Victoria White Granite Co., Milford.

The granite (specimens D, XXVIII, 14, d, e, g, h), "Milford pink," is a biotite granite of light pinkish-gray color with more or less conspicuous black spots. The general color is more pinkish than that of the Cutting quarry stone. Its texture is somewhat gneissoid, medium to coarse. Feldspar and mica measure up to 0.5 inch, but the feldspar individuals merge into lenses an inch long, as do also the quartz and biotite. The length and width of the biotite spots in any surface depends upon whether that surface is parallel to the plane of the flow structure or to its side, or crosses it. The quartz areas are always granular, with particles up to 1.75 millimeters across. The rock consists of these minerals in descending order of abundance: A light-pink potash feldspar (microcline and orthoclase) with some intergrown soda-lime feldspar, slightly kaolinized; quartz (with minute cavities arranged in sheets), which in the aggregate has a very pale bluish tinge; a milk-white to light-greenish striated soda-lime feldspar (albite to oligoclase-albite), partly kaolinized and crowded with minute particles and crystals of epidote and zoisite, with a few

scales of white mica and rarely calcite; biotite (black mica), some of it chloritized, rarely containing ilmenite, with a rim of leucoxene. Accessory: Garnet, apatite, magnetite and pyrite (rare), ilmenite, zircon, allanite (up to 0.6 millimeter), rimmed with epidote. Secondary: Kaolin, a white mica, epidote zoisite, leucoxene, chlorite, calcite. The merging of the particles by the gneissoid structure vitiates somewhat the application of the Rosiwal method of estimating the mineral percentages, and the great variation in the amount of biotite on different specimens also affects the results. Four tests on two specimens with meshes 0.5 inch and a total linear length of 28.8 inches yielded these results:

Estimated mineral percentages in gneissoid granite from East quarry, Milford, Mass.

Feldspar	49.92	58.47	68.22	70.83
Quartz	41.08	35.08	26.92	24.45
Biotite	9.00	6.45	4.86	4.72
	100.00	100.00	100.00	100.00

The following analysis of this granite, made for the company by Prof. R. H. Richards at the Massachusetts Institute of Technology, is given here for reference:

Analysis of granite from the East quarry, Milford, Mass.

Silica (SiO_2)	72.02
Alumina (Al_2O_3)	14.43
Iron oxide (FeO)	.89
Iron sesquioxide (Fe_2O_3)	1.25
Manganous oxide (MnO)	.33
Lime (CaO)	1.18
Magnesia (MgO)	Trace.
Potash (K_2O)	5.41
Soda (Na_2O)	5.85
Loss in ignition	.35

The durability of the polished face on outdoor exposure will vary according to the size and number of the biotite particles.

The quarry in 1906 measured about 100 feet from north to south by 300 feet across and 40 to 80 feet deep.

Rock structure: The chief feature is a vertical granite dike 4 feet thick crossing the quarry diagonally. It is a biotite granite of medium to dark greenish to gray color with pinkish spots. Its texture is fine to medium, with porphyritic feldspars up to 0.6 inch and exceptionally to 1.3 inches in length. The matrix consists largely of greenish soda-lime feldspar (oligoclase-albite), partly kaolinized and epidotized; a slightly bluish granular quartz, the colors of these two minerals giving the rock a general bluish-green tinge; and biotite (black mica). The large pink crystals are potash feldspar (orthoclase with minutely intergrown soda-lime feldspar, also microcline). There is also some potash feldspar in the groundmass. Accessory: Garnet, apatite (fairly abundant), zircon, allanite. Secondary: Kaolin, muscovite, chlorite, epidote, zoisite, calcite. This dike contains black segregations (inclusions?), mainly of biotite with slightly bluish quartz and epidote. The granite has a flow structure marked by darker bands striking N. 10° W. and dipping 40° E.

The granite also contains irregular inclusions, from 1 to 2 feet in diameter, of a dark-gray and black banded, very fine grained, somewhat schistose mica diorite (quartz, biotite, and plagioclase, with pyrite, magnetite, and epidote). The rift is reported as horizontal, and the grain as vertical. The sheets, 1 to 15 feet thick, dip 10°–15° SSW. The courses of dike, flow, grain, and joints are shown in figure 83. Joints (A), dip 80° E., recur at intervals of 100 to 200 feet; (B), dip 45°–50° SSW., spaced 3 feet and over; (C), dip 45° N.; (D), one only, dip 60° NW.; (E), dip 45° W., slickensided horizontally. The face of (A) on the west wall is coated with a mass of minutely brecciated granite 1½ inches thick, cemented with calcite, chlorite, fibrous muscovite, and limonite. Rusty stain along the sheets is from 6 inches to 2 feet thick.

Transportation, by siding from Boston & Albany Railroad.

The product is used mainly for buildings. Specimens: Hanover National Bank, New York; Boston Public Library; public library, Columbus, Ohio. In

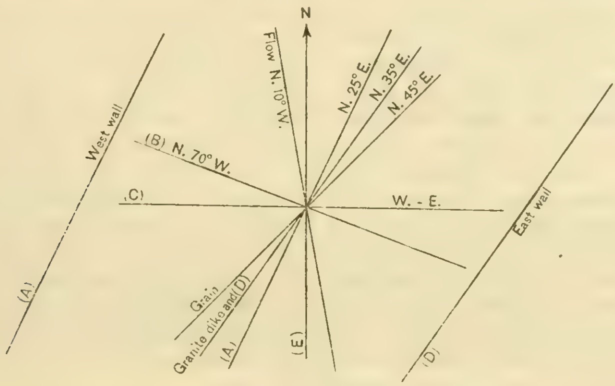

FIGURE 83.—Structure at East quarry, Milford, Mass.

1906 this quarry was furnishing part of the stone for the basement of the National Museum at Washington and part of that for the Pennsylvania Railroad terminal at New York.

The **Bay State quarries** are in Milford Township, 1¾ and 2 miles north-northeast of Milford. (See fig. 81.) Operator, Pink Granite Co. of Milford, Milford.

The granite (specimens D, XXVIII, 16, a, b), "Milford pink," is a biotite granite of light pinkish-gray color, like that of the Cutting quarry (p. 344) but with more conspicuous greenish feldspars and much smaller spots of black mica. Its texture is medium to coarse, even-grained, with very little if any gneissnoid structure. The feldspars measure up to 0.5 inch, the black mica to 0.3, rarely 0.4 inch, and the quartz is granular. Its constituents, in descending order of abundance, are a delicate pink potash feldspar (orthoclase and microcline, both inclosing large particles of soda-lime feldspar); quartz with some cavities in sheets, clear, not bluish; a milk-white to light-greenish soda-lime feldspar (albite to oligoclase-albite), partly kaolinized and epidotized, also with some white mica and calcite; biotite (black mica), some of it chloritized. Accessory: Garnet, magnetite, pyrite. Secondary: Kaolin, a white mica, epidote, zoisite, calcite.

A partial analysis, leaving out potash and soda, made for the company by Prof. R. H. Richards, of the Massachusetts Institute of Technology, is given here for reference:

Partial analysis of granite from West quarry, Milford, Mass.

Silica (SiO_2)	75.77
Alumina (Al_2O_3)	13.59
Iron oxide (FeO)	.52
Iron sesquioxide (Fe_2O_3)	1.14
Manganese oxide (MnO)	.24
Lime (CaO)	.94
Magnesia (MgO)	Trace
Loss on ignition	.49
	92.69

The old "West" quarry, opened about 1887, measured in 1906 about 300 by 175 feet and 40 feet in depth. A new quarry was opened in 1915 a little northeast of it.

Rock structure at West quarry: There are on the east side conspicuous vertical dikes of medium-gray fine-grained quartz monzonite, 0.5 inch to 2 feet thick, strike N. 20° W., occurring at intervals of 20 to 100 feet. This consists of clear potash feldspar and cloudy light-gray soda-lime feldspar in almost equal amounts, the latter kaolinized, micaized, and altered to epidote and zoisite; quartz, with hairlike crystals of rutile and cavities; biotite, some of it altered to chlorite. Accessory: Garnet, etc. Secondary: Kaolin, a white mica, epidote, zoisite, chlorite, calcite. There are two schist dikes already described on page 56. One on the north wall, 2 feet thick, strikes N. 65°–70° W. and dips 65° NNE.; another, farther south, 20 inches thick, strikes about northwest and is vertical. The sheets, 2 to 15 feet thick, are nearly horizontal at the north end of the quarry but dip 15°–20° at the south end. The sheets become irregular at the bottom. Vertical joints, strike north to N. 10° E., spaced 10 to 100 feet, form a heading on west side. One at the north end strikes N. 60° W. and dips curving 45°–50° SW.

Transportation, by track one-half mile to New York, New Haven & Hartford Railroad.

Product, specimens: John Hancock Insurance Co. Building, Federal Street, Boston; Amherst College Library, Amherst, Mass.; Chamber of Commerce, Rochester, N. Y.; customhouse, Wilmington, N. C.; E. T. Stotesbury residence, Chestnut Street, and Plaza Hotel, South Broad Street, Philadelphia; part of basement of National Museum and approaches to Lincoln Memorial, Washington.

The **Norcross quarry** is in Milford Township, nearly 2 miles northeast of Milford and about one-fourth mile east of the East quarry. (See fig. 81.) Operators, Dodds Bros., Milford. Idle since 1905.

The granite (specimen D, XXVIII, 15, a) "Milford pink," is a biotite granite of light pinkish-gray color with more or less conspicuous black spots. The general color is like that of the granite in the East quarry, described on page 345, but is marked by light blood-reddish stains not over 0.25 inch across and an inch or two apart. Its texture is like that of the granite in the East quarry. The quartz grains measure up to 1.1 millimeters. Its constituents are also the same, but with the addition of red hematitic stains, which originate presumably in the oxidation of magnetite particles.

The quarry measured in 1906 175 feet from northeast to southwest by 100 feet across and about 70 feet in depth.

Rock structure: The sheets, up to 15 feet thick, have a low north dip. Joints strike about northeast, dip over 50° NW., form the northwest and south-

east walls. Another set with a similar strike dips 30°–45° SE., and is spaced 8 to 10 feet. A third set strikes about north or diagonally to quarry and appears on the southwest wall. The rift is reported as better than at some of the other Milford quarries. Rusty stain is up to 2 feet thick.

The **Massachusetts Pink quarry** is in Milford Township, 2½ miles north of Milford, at the north end of a low north-south ridge. (See fig. 81.) Idle since 1914.

The granite (specimen D, XXVIII, 21, b), "Milford pink," is a biotite granite of a very slightly pink-tinted light-gray color with conspicuous black spots. Its texture is somewhat gneissoid, medium to coarse; in other respects and in mineral composition it closely resembles the stone of the Cutting quarry, described on page 344.

The quarry, opened in 1902, was in 1906 300 feet from east to west by 200 feet across and from 10 to 35 feet deep.

Rock structure: A schist dike, 2 feet thick, on the west side, striking N. 3° W. and dipping 55° E., has already been mentioned on page 56. The sheets, 4 to 25 feet thick, dip low east. There are three sets of joints—(a), strike N. 35° W., dip 65° E., spaced 100 feet; (b), strike N. 55°–60° E., dip 90°, spaced 30 feet; (c), strike N. 55° W., dip 40° W. The rift is reported as horizontal, and the grain as vertical from east to west. Rusty stain is up to 3 inches thick on the lower sheets.

Transportation, by cart 3 miles to cutting shed at New York, New Haven & Hartford Railroad track.

The product is used for buildings, bridges, and mausoleums. Specimens: Bridge over Bronx River, Bronx Park, New York; Rochester Safe Deposit & Trust Co. Building, Rochester, N. Y.; Bloomingdale mausoleum, Greenwood Cemetery, N. Y.; McKinley national memorial, Canton, Ohio.

The **Hopkinton quarry** is in Hopkinton, Middlesex County, a mile south of Hayden Row and about 3¾ miles north-northeast of Milford. (See fig. 81.) Idle since 1914.

The granite (specimen D, XXVIII, 22, a) is a biotite granite of medium, slightly pinkish gray color with fine black specks. Its texture is even-grained, medium, with feldspars generally up to 0.4 inch and mica to 0.2 inch. It is thus pinker and finer grained than that of the Massachusetts Pink quarry. Its constituent minerals, in descending order of abundance, are a pinkish potash feldspar (orthoclase and microcline), inclosing particles of soda-lime feldspar and slightly kaolinized; faintly rose-colored granular quartz in particles up to 1.37 millimeters; a grayish or greenish-gray soda-lime feldspar (albite to oligoclase-albite), a little kaolinized and epidotized, with some white mica; biotite (black mica), some of its chloritized. Accessory: Garnet, magnetite, apatite, zircon, allanite (bordered with epidote). Secondary: Kaolin, epidote, zoisite, chlorite, a white mica.

The quarry in 1906 was 50 feet square and 25 feet deep.

Product: The Bishop mausoleum, Sleepy Hollow Cemetery, Tarrytown, N. Y.

The **Maguire quarry** is in Hopkinton, half a mile west of Echo Lake and 3¾ miles N. 5° W. of Milford. (See fig. 81.) Quarry idle.

The granite is a biotite granite of a very slightly pink-tinted light-gray color with conspicuous black spots. In texture and constituents it is reported as corresponding to the stone of the Cutting quarry, described on page 344.

The quarry, opened in 1906, measured then 300 by 100 feet and up to 15 feet in depth.

The sheets are reported as dipping about 20° NE.

Transportation, by cart 1 mile to cutting shed on railroad siding.

The **Echo Lake quarry** is in Milford Township near the Hopkinton line and Echo Lake, 3½ miles N. 5° E. of Milford. (See fig. 81.) Quarry idle.

The granite is a biotite granite of slightly pink tinted light-gray color, reported as a little more pinkish than that of the Cutting quarry, described on page 344.

The quarry, opened in 1906, measured then 60 by 40 feet and up to 20 feet in depth.

The sheets are reported as dipping about 20° W., but irregular. A "soft heading"—that is, a schist dike like that at the Cutting quarry, described on page 56—is reported as forming the west side of the quarry, with a north-northwest strike.

Transportation, by cart 1 mile to cutting shed on railroad siding.

The **North Milford quarry** is in Milford Township, 2½ miles about N. 7° W. of Milford and one-third mile southwest of the Massachusetts Pink quarry. (See fig. 81.) Operator, North Milford Granite Co., Milford. Idle since 1908.

The granite is a biotite granite of very slightly pink-tinted light-gray color with conspicuous black spots. In texture and constituents it is identical with the stone of the Cutting quarry, described on page 344.

The quarry, opened in 1905, was in 1906 100 feet square and averaged 5 feet in depth.

Rock structure: Owing to the irregularity of sheets this is a "boulder quarry." Vertical joints strike N. 80° E. and N. 25° E. The rift is reported as horizontal and the grain as vertical, with N. 80° E. course.

Transportation, by cart 2½ miles to New York, New Haven & Hartford and Boston & Albany railroads.

The product is used for construction. Specimens: The granite part of Redmond Bank Building, 31 Pine Street, and trimmings for tenements of Homes Suburban Co., One hundred and fifty-sixth Street, New York; trimmings for residence of Hennen Jennings, northeast corner of Massachusetts Avenue and Sheridan Circle, Washington. Quarry not operated in 1916.

The **Carroll quarry** is in Milford Township, 1¾ miles north of Milford and half a mile north-northwest of Cedar Swamp Pond. (See fig. 81.) Operator, Webb Pink Granite Co., 40 Crescent Street, Worcester. (Quarry designated Nos. 4 and 5 by the company.) Now idle.

The granite (specimen D, XXVIII, 18, b) is a biotite granite of light-gray shade with conspicuous black spots. This is the whitest of the Milford granites. Its texture is somewhat gneissoid, medium to coarse, with feldspars and mica up to 0.5 inch across and with finely granular quartz. Its constituents, in descending order of abundance, are cream-colored to palest-pink potash feldspar (orthoclase and microcline), with minutely intergrown soda-lime feldspar and slightly kaolinized; clear, not bluish quartz in grains up to 0.5 millimeter, and with cavities some of which are in sheets; clear to cloudy, some very pale greenish soda-lime feldspar (albite to oligoclase-albite), not a little kaolinized and epidotized; biotite (black mica), some of it chloritized. Accessory: Garnets (minute and usually in rows), apatite, fluorite, allanite (rimmed with epidote), zircon. Magnetite and pyrite not observed. Secondary: Kaolin, epidote, zoisite, chlorite, calcite, white mica.

The following analysis of this granite, made for the company by Robert C. Sweetzer, of the Worcester Polytechnic Institute, in 1905, is given here for reference:

Analysis of granite from the Carroll quarry, Milford, Mass.

Silica (SiO_2)	76.52
Alumina (Al_2O_3)	12.21
Iron oxide (FeO)	2.66
Lime (CaO)	.79
Magnesia (MgO)	.13
Potash (K_2O)	4.68
Soda (Na_2O)	2.86
Water (H_2O)	.41
	100.26

Specific gravity 2.633.

The quarry, opened in 1905, measured in 1906 about 500 by 200 feet and up to 30 feet in depth.

Rock structure: The sheets, 6 inches to 15 feet thick, undulate horizontally. The rift is reported as horizontal, and the grain as vertical, with N. 65° E. course. Joints (a), strike N. 60° W., dip 90°, spaced 10 to 60 feet; (b), strike N. 20° E., dip 90°, form headings at the northwest and southeast sides and in the middle; (c), strike N. 80° W., dip 45° S., one in the middle and another 25 feet east of it. Rusty stain is 2 inches thick on sheet surfaces.

The product of this quarry is combined with that of the next.

The **Webb quarries Nos. 7 and 8** are in Milford Township, 2 miles north of Milford. (See fig. 81.) Operator, Webb Pink Granite Co., 40 Crescent Street, Worcester. Quarry idle.

The granite (specimens D, XXVIII, 17, a, b), "Milford pink" is a biotite granite of medium pinkish and greenish-gray color, with black spots which are not as conspicuous as those of the stone in the Carroll and Cutting quarries. Its texture is even-grained, medium, with feldspars up to 0.4 inch and mica up to 0.2 inch in diameter and finely granular quartz. Its constituents, in descending order of abundance, are a delicate pink potash feldspar (orthoclase and microcline), minutely intergrown with soda-lime feldspar and with quartz and more or less kaolinized; a very faintly bluish finely granular quartz with cavities some of which are in sheets; a yellow-greenish to clear soda-lime feldspar (albite to oligoclase-albite), generally kaolinized and epidotized also with some scales of white mica and chlorite; biotite (black mica). Accessory: Magnetite, apatite, zircon. Secondary: Kaolin, epidote, zoisite, chlorite, a white mica.

An estimate of the mineral percentages by the Rosiwal method with ½-inch mesh and total linear length of 46.5 inches yields these results: Feldspar, 55.91; quartz, 35.66; biotite, 8.43.

W. T. Schaller, chemist, of this Survey, extracted from an average specimen of this granite, by means of hot dilute acetic acid, 0.04 per cent of CaO (lime), which indicates the presence of 0.07 per cent of $CaCO_3$ (calcium carbonate, calcite). This lime is of course irrespective of that combined with silica in the oligoclase feldspar and epidote.

The stone takes a fair polish, but the mica particles are sufficiently large to detract from the durability of the polish in prolonged outdoor exposure.

The quarry, opened in 1905, measured in 1906 about 250 by 200 feet and up to 30 feet in depth.

Rock structure: A flow structure, shown by biotitic streaks, strikes N. 40° W. and dips 50° NE. The sheets, 5 to 12 feet thick, are horizontal in irregular undulations. Joints (a), strike N. 40° W., dip 90°, spaced 3 to 10 feet; (b),

strike N. 15° E., dip 75° E., recur at an interval of 8 and one of 50 feet. The rift is reported as horizontal, and the grain as vertical, with an east-west course.

Transportation from these quarries, by tracks 3,750 feet to sidings of New York, New Haven & Hartford Railroad.

Product, specimens from all this company's quarries except the next: Union Station, Baltimore; courthouse and municipal building, Wilmington, Del.; Commercial National Bank, Chicago; Cuyahoga courthouse, Cleveland, Ohio; John Hancock Building No. 2, Boston; new post office, New York.

The **Webb No. 10 quarry** is in Milford Township, two-thirds mile east of the northern part of Cedar Swamp Pond. (See fig. 81.) Operator, Webb Pink Granite Co., 40 Crescent Street, Worcester. Idle since 1917.

The granite, "Milford pink," is reported as resembling in color that of the East quarry, described on page 345, but with a somewhat finer texture, the biotite spots being more sparse and less elongated so as to have practically the same appearance on rift, grain, and hardway faces.

The quarry is about 300 by 100 feet, with a working face of 30 feet, part above and part below the ground level.

Product: This quarry supplied the granite for the Freer Art Collections Building of the Smithsonian Institution, Washington.

UXBRIDGE.

The Uxbridge quarries are 8 miles southwest of Milford and nearly 15 miles south-southeast of Worcester. (See map, Pl. XXIII.)

The granite of Uxbridge is in an area about 17½ by 10 miles designated on the map of Bulletin 597 "Northbridge granite gneiss (porphyritic granite largely crushed to gneiss)" and referred doubtfully to the Archean. (See pp. 155, 156 of that bulletin.)

The **Blanchard quarries** are in Uxbridge Township, about 1½ miles west-northwest of Uxbridge station and 1¾ miles south-southeast of Whitinsville. (See Blackstone topographic map, U. S. Geol. Survey.) Operator, Blanchard Bros. Granite Co., Linwood.

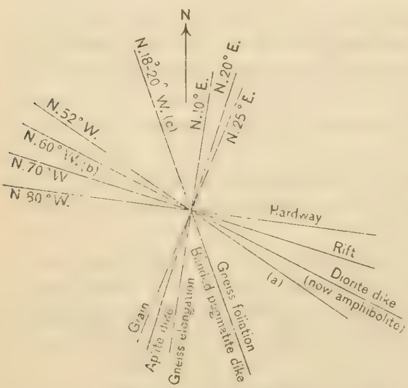

FIGURE 84.—Structure at Blanchard quarries, Uxbridge, Mass.

The granite (specimens D, XXX, 114, d, e), "Uxbridge," is a biotite granite gneiss of light to medium gray shade (light gray on rift face and medium gray on hard-way face) and of medium porphyritic, elongated gneissic texture, with feldspars up to 0.4 inch (exceptionally 0.5 inch) and laminae of quartz and mica up to 0.1 inch wide, alternating with laminae of feldspar up to 0.3 inch wide. Its constituents, in descending order of abundance, are light-buff potash feldspar (microcline and orthoclase), slightly micacized; light smoky quartz with cavities in parallel and rectangular sheets; milk-white soda-lime feldspar (oligoclase); biotite (black mica); and a little muscovite or bleached biotite. Accessory: Magnetite, apatite, purple fluorite. Secondary: Carbonate, epidote, kaolin, muscovite. Effervesces slightly with muriatic-acid test.

This gneiss resembles that of Sterling, Conn., and is a useful constructional stone.

The quarries, begun in 1864, consist of two openings. The larger in 1910 measured 300 by 200 feet and 20 to 50 feet deep, and the smaller, triangular in area, 100 feet on a side and 60 feet deep in the center.

Rock structure: As sheet structure is absent this is a "boulder quarry." The courses of the joints, foliation, etc., are shown in figure 84. Joint set (A), dip 77° S. 38° W., spaced 5 to 40 feet; (B), dip 30° N. 45°–60° E., spaced 3 to 20 feet; (C), dip 55° S. 72° W., spaced 10 to 60 feet. The foliation dips 35° N. 70° E. The rift dips 10°–15° N. 20° E., and the grain and hard way are vertical. Aplite dikes are 2 inches to 3 feet thick. Pegmatite dikes of banded quartz and feldspar (described on p. 51) parallel to joints (C) are up to 3 feet thick, and an amphibolite dike (described on p. 54) parallel to joints (B) is 6 to 18 inches thick. The amount of sap varies greatly. Some blocks are free from it, some are all stained, on others it is a foot thick.

Transportation, by private siding to New York, New Haven & Hartford Railroad, 1½ miles.

LEOMINSTER.

The **Leavitt quarry** is in Leominster Township, 2 miles west of that village and about 400 feet above it. (See Fitchburg topographic map, U. S. Geol. Survey, and Pl. XXIII.) It was last operated in 1916 by L. F. Burrage, of Leominister, but is now disused.

The granite (specimen D, XXX, 110, a), "Leominister," is a mica diorite of dark bluish-gray color (between "Barre dark" and "Quincy extra dark") and of very fine, even-grained texture, with particles under 0.1 inch. Its constituents, in descending order of abundance, are light-grayish soda-lime feldspar (oligoclase-andesine); biotite (black mica), with rare muscovite or bleached biotite; and very light smoky quartz. Accessory: Titanite (fourth in order of abundance), plentiful apatite needles, zircon crystals in strings, also branching, and pyrite. Secondary: Carbonate, chlorite. It effervesces with muriatic-acid test.

This is a handsome fine-grained dark stone, suitable for monuments or buildings. It ought to hammer light.

The quarry, opened in 1870, measured in 1910 300 feet north and south by 200 feet across and 5 to 30 feet deep.

Rock structure: The sheets, 6 inches to 5 feet thick, but mostly under 18 inches, dip 20° E. There are two sets of joints—(a), vertical, strike N. 80° E., forms the south wall; (b), vertical, strike N. 5° E., dip steeply east to 90°, forms the east and west walls. The rift is parallel to the sheets, and the grain vertical north to south. The quarry is crossed diagonally by a large ramifying dike of banded aplite and pegmatite, described on page 45, a horizontal section of which is shown in figure 2. Minor dikes of aplite and also of pegmatite intersect the main dike. One 4 feet 6 inches thick is on the west wall. The diorite also has here and there white feldspar "knots" up to 1.5 inches across.

Transportation, by cart 2¼ miles to Leominister station.

The product was used for buildings, trimmings, curbing, flagging, and foundations. Specimens: Haws Memorial Chapel, Evergreen Cemetery; trimmings to Mayo and Jones blocks, Leominister; trimmings to Acre School, Clinton, Mass.

FITCHBURG.

On the geologic map of Bulletin 597 the granite of Rollstone Hill,[54] a mile west of Fitchburg station, is in an area extending from the vicinity of Worcester

[54] This hill takes its name from a glacial boulder, 10 by 8 feet, of porphyritic granite with 3-inch feldspars, resting on its summit.

to and beyond the New Hampshire line, designated "Fitchburg granite (white muscovite-biotite granite)" and regarded by Emerson as of late Carboniferous or post-Carboniferous age.[55]

The **McCauliff quarry** is on the west side of Rollstone Hill in Fitchburg, a mile a little south of west of the Boston & Maine Railroad station. (See Fitchburg topographic map, U. S. Geol. Survey, and Pl. XXIII.) Operator, B. F. McCauliff Quarry Co. (Inc.), Fitchburg.

The granite (specimen D, XXX, 107, a) is a muscovite-biotite granite gneiss of light to medium bluish-gray color and of gneissic medium texture, with feldspars up to 0.3 inch and micas up to 0.2 inch. Its constituents, in descending order of abundance, are clear to translucent bluish potash feldspar (microcline and orthoclase); light smoky quartz, finely granulated (particles under 0.37 millimeter), with rutile needles and cavities; milk-white soda-lime feldspar (oligoclase-albite), kaolinized and micacized; muscovite (white mica) and fibrous muscovite in stringers; and biotite (black mica), some of it chloritized. Accessory: Garnet, apatite. Secondary: Kaolin, white mica, epidote, chlorite. No effervescence with muriatic acid test.

This is a constructional granite gneiss of bright mineral contrasts.

The quarry, opened about 1865, is triangular in area, measuring in 1910 about 450 feet on its north side and 175 feet on its east side, which are the working faces, and 10 to 20 feet deep.

Rock structure: The sheets, 1 to 8 feet thick, horizontal at the northeast corner of the quarry, dip away radially to an angle of 15° in its lower part. There are four sets of joints—(*a*), strike N. 75° W. to N. 75° E., dip 65° about south, spaced 3 to 20 feet, forms the north wall, and the joints are tight and ferruginous; (*b*), vertical, strike N. 5° W., only a few; (*c*), strike N. 60° E., dip 75° S. 30° E., spaced 12 feet and over, few and loose; (*d*), strike, N. 20° W., dip 45° S. 70° W., three only, 20 to 150 feet apart. The gneiss foliation strikes N. 10° E. and dips 55° N. 80° W. The rift is horizontal and the grain vertical, with N. 80° E. course. There are a number of pegmatite dikes up to 4 inches thick, with black tourmaline dipping 45° about north and spaced 15 feet and over. Some of these dikes meander and combine. One is faulted along a N. 20° E. plane. Another has a 0.5 inch central band of smoky quartz and borders of feldspar and tourmaline. The stone is generally sound except near the main joints and for 2 or 3 inches along sheet surfaces.

Transportation, by cart one-eighth mile to railroad siding.

The best of the product is used for base courses, the seconds for curbing and paving, and the waste for concrete. Specimen: First story of high school, Fitchburg.

The **Litchfield quarry** is on the southwest side of Rollstone Hill in Fitchburg, nearly a mile west-southwest of the Boston & Maine Railroad station. (See Fitchburg topographic map, U. S. Geol. Survey, and Pl. XXIII.) Operator, B. F. McCauliff, Fitchburg.

The granite is identical with that of the McCauliff quarry.

The quarry, opened in 1875, is triangular in area, 700 feet in a northerly direction by 200 feet and 75 feet.

Rock structure: The sheets, 6 inches to 6 feet, some 15 feet thick, curve gently westward from the top of the hill. There is but one set of joints, strike N. 70° E., dip 45° S. 20° E., two only, 50 feet apart, discontinuous. Foliation, rift, and grain are as at the McCauliff quarry. Pegmatite dikes up to 6 inches dip 50° NE.; at the southeast end is one, 2 feet thick, of smoky quartz, feldspar, muscovite, and black tourmaline. Some of these dikes

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[55] See Bull. 597, pp. 231–233, and on the minerals of Rollstone Hill, p. 237.

are very micaceous, becoming the "sand seams" of quarrymen. The "sap" is 6 inches thick on the top sheets.

The product is used for dimension stone, curbing, and paving. The smallest size from the crusher is used for graveling roofs. Specimens: Wallace Way, steps and buttresses to high school, and most of the stone in Episcopal Church chapel, Fitchburg.

The **Godbeer quarry** is on the northeast side of Rollstone Hill, in Fitchburg, about three-fourths mile west of the Boston & Maine Railroad station. Quarry no longer operated. Last operator, Henry Godbeer. Fitchburg.

The granite is identical with that of the McCauliff quarry.

The quarry in 1910 measured 250 feet in a northeast direction by 200 feet across and 5 to 10 feet deep.

Rock structure: The sheets, 1 to 8 feet thick, dip 20° NE. Their variation in thickness is due to incomplete formation. There are three sets of joints—(*a*), vertical, strike N. 40°–60° E., spaced 10 to 20 feet, has rusty faces; (*b*), strike N. 80° E., dip 55° S. 10° E., few; (*c*), strike N. 60° W., dip 40° S. 40° W., few.

Transportation, by cart half a mile to railroad siding.

The product was used for building and curbing. Specimen: Third story of Moran Building, Fitchburg.

CONNECTICUT.

GEOLOGIC RELATIONS.[55a]

By H. E. Gregory.

OUTLINE OF GEOLOGIC HISTORY OF CONNECTICUT.

Whether the area now occupied by Connecticut was land or sea at the beginning of geologic time is unknown. It is probable, however, that some of the gneisses and schists antedate the appearance of life on the earth. Unfortunately no fossils have been found in the older rocks of the State, and all that can be said with assurance regarding the age of these formations is that they were in existence long prior to Triassic time. Pre-Cambrian time is believed to be represented by the Becket gneiss, which outcrops over wide areas in northern Litchfield County. This rock is, however, so profoundly changed that it is impossible to determine with accuracy the original from which the present complex mass was derived. The limestone and marbles of Canaan and Danbury were probably deposited in Cambro-Ordovician time, and the material forming these rocks is believed to have been furnished by high land masses located east of the Rhode Island border—lands which long ago disappeared.

[55a] The sections on the geologic history of Connecticut, the distribution of its granites and gneisses, and the nature and age of its granitic intrusions are reproduced from U. S. Geol. Survey Bull. 484.

The geologic history of the immensely long time represented by the Silurian, Devonian, and Carboniferous ages has not yet been completely deciphered. Whether rocks belonging to these ages exist in western Connecticut is unknown, but the metamorphosed equivalents of Carboniferous sediments are represented in the eastern part of the State. Though much doubt exists regarding the Paleozoic sedimentary record, there is abundant evidence for the statement that at frequent intervals during these ages igneous intrusions occurred. Masses of igneous rock, which occur as minute dikes and sheets, may be considered as remnants of larger masses, which were poured out on the surface or hidden beneath the overlying strata.

Moreover, an examination of the schists and gneisses of the State reveals the fact that all rocks older than the Triassic sandstone have been involved in movements within the earth's crust and have accordingly been so much metamorphosed as to destroy all fossils which they may have contained and to modify the rocks themselves beyond recognition. The dates when these far-reaching changes took place are believed to coincide with the mountain-making epochs marking the close of Ordovician and of Carboniferous time. The extent of these changes and their fundamental character are revealed by a study of the metamorphic rocks of the State.

These rocks are chiefly schists and gneisses, and accordingly have structures indicating that they have been profoundly changed from their original sedimentary or igneous character. The original component minerals have been rearranged, stretched, and drawn out in lines; new minerals have been produced; parts have been fused and recrystallized. Instead of horizontal layers or uniform igneous masses, we find twisted and broken rock with layers, bands, and ribbon structures in every conceivable position. Moreover, this tangle of structure is further complicated by the presence of dikes, seams, and veins which have made their way into the rock at different stages of its history. In looking at this confused mass of rock which forms the Connecticut crystallines it seems apparent that it has taken part in manifold changes which went on in the earth's crust for ages.[56]

The mountains and plateaus of Carboniferous time were worn down during Triassic time, and the materials of which they were composed have gone to make the sandstone of central Connecticut. The amount of rock removed from Connecticut prior to Triassic time may be judged from the appearance of the rock immediately underlying the Mesozoic strata. The structure of the schists which form the floor of the Triassic is such as can be produced only at depths a mile or possibly several miles below the earth's surface. We may be reasonably sure, therefore, that mountains of folded strata once occupied Connecticut and that the granites and gneisses and schists which we see are but the stumps of lofty land masses "rivaling the Alps in height and ruggedness."

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[56] Connecticut Geol. and Nat. Hist. Survey Bull. 6, p. 80.

During the formation of the conglomerates, sandstones, and shales—a time proved by dinosaur and fish remains to be Triassic—lava was poured out over central Connecticut and possibly over the entire State. Remains of these flows of basalt now stand as a ridge separating the valleys of Farmington and Connecticut rivers. During Cretaceous time the highlands were lowered and the entire surface was reduced practically to a plain sloping from northwest to southeast, and the Cretaceous sediments now exhibited on Long Island probably also covered southern Connecticut. This plain (peneplain) formed during Cretaceous time was uplifted during early Tertiary time, and the streams were thereby given greater eroding power and began at once to deepen and widen their valleys. Continued erosion during the millions of years comprehended in Tertiary time resulted in giving to Connecticut the larger features of valley and hill, highland and lowland, which exist at the present time.

During the Pleistocene ("glacial") epoch the surface features of Connecticut were again remodeled. The more prominent erosion forms of Tertiary time remained, but the details of the scenery were completely changed. Hills were rounded off, valleys were filled, and the entire State was covered with a mantle of glacial débris. Drainage lines were rearranged and the lakes, swamps, and bogs so characteristic of the State were formed. Decomposed rock and "rotten rock" were largely removed from the ledges, leaving fresh rock near the surface. This last-mentioned result of glaciation is of interest to quarrymen, as the expense and difficulty of procuring commercial stone have thereby been greatly lessened.

DISTRIBUTION OF GRANITE AND GNEISSES IN CONNECTICUT.

The areas of granite gneiss in Connecticut are shown on the map forming Plate XXVIII. The true granites occur in masses so small that they are not shown on this map. In fact, unchanged granite occupies probably less than one-half of 1 per cent of the 4,990 square miles of the State. It will be noticed that the granite gneisses occur either as long, narrow bands, as illustrated by the Glastonbury and Monson gneisses, in larger areas of irregular outline like the Sterling and Becket gneisses, or in rock masses surrounded entirely by schist, as at Bristol and Collinsville. As all of the granite gneisses of the State are adapted for use as structural material, and some of them also for road metal, and as those who are interested in the quarry industry may wish to examine these various types of granite gneiss, the following brief description is given of the more important formations.[57]

[57] Abstracted from Connecticut Geol. and Nat. Hist. Survey Bull. 7, pp. 33–38.

Becket gneiss.—Is light gray in color, of firm texture, and has a uniform banded structure. In many places the rock is highly quartzose and granular. The formation includes many veins of quartz and pegmatite. Supposed to be of pre-Cambrian age.

Prospect porphyritic gneiss.—Is light gray in color. The gneissoid appearance is produced by bands of granular quartz and feldspar interbedded with layers composed chiefly of biotite. The porphyritic mineral is usually orthoclase, white or pink in color, varying from one-sixteenth inch to 3 inches in length. The rock is believed to have been a granite porphyry intruded into the Hartland schist.

Bristol granite gneiss.—Typical rock is light gray, with gneissoid structure more or less developed by the presence of layers of biotite; more schistose layers contain muscovite. An evenly banded hornblende gneiss occupies part of the area. Garnet is nearly everywhere present and in places rises to the rank of a principal mineral. The rock was originally a mass of granite and diorite intruded into Hartland schist.

Collinsville granite gneiss.—Two types appear intermingled without order, a light gray, heavy-bedded rock, grading into massive granite, and a very dark gray to black variety, which grades by imperceptible stages into evenly banded hornblende gneiss. The rock consists of feldspar, largely orthoclase, quartz in irregular grains, and biotite. Was originally granite and diorite intruded into Hartland schist.

Brookfield diorite.—Is usually massive, but shows also gneissoid and even schistose phases. Both light and dark types are present, the former containing much quartz, and in extreme cases no dark mineral except biotite. The dark variety shows an almost complete absence of quartz, and in its place dark hornblende. It is an igneous mass intruded into the quartzite and schists of this region.

Danbury granodiorite gneiss.—The rock presents two important facies—a biotite granite and a diorite in which hornblende becomes an important constituent and quartz is less prominent. There are gradations between the two types. It is prevailingly porphyritic, with pink or white phenocrysts of feldspar, is igneous in origin, and was intruded prior to the time when metamorphic action converted igneous and sedimentary rocks alike into gneisses and schists.

Thomaston granite gneiss.—Rock varies in structure from an almost massive granite to a rock with distinctly schistose phases. It is of igneous origin, as shown by the fact that it often occurs as dikes, and fragments of other rocks are included in it.

Glastonbury granite gneiss.—Two types—a granite biotite gneiss or a biotite granite, in a narrow band along the eastern border, and a darker, well foliated gneiss, with biotite, hornblende, and epidote, in the remainder of the area. Both massive and schistose phases sometimes become augen gneiss. Believed to be of igneous origin.

Monson granite gneiss.—Where typically exposed, the rock is a fine-grained, dark-gray, uniform biotite-hornblende gneiss, marked at short intervals by parallel seams of quartz, and with bands of biotite and hornblende. It is believed to be of igneous origin.

Eastford granite gneiss.—In general, a light or dark gray gneiss, fine grained, or in places even porphyritic. The composition and texture show the rock to be of igneous origin.

Sterling granite gneiss.—The rock is pink or gray in tone, and is made up of two distinct types—a porphyritic gneiss with an abundance of biotite along foliation planes, and an aplite or granite gneiss practically free from mica.

The porphyritic type is always highly gneissoid and the phenocrysts of pink feldspar are drawn out into lenticular forms. Where phenocrysts are absent the rock shades into a normal granite, which is intermediate between the two above-mentioned types. The aplitic type is probably a later intrusion than the porphyritic and normal types. Origin, igneous.

Willimantic gneiss.—In general, the rock is coarse grained and often porphyritic in structure, usually considerably crumpled and folded. There are two varieties, the light and the dark. The light variety consists of quartz, feldspar, and biotite, in the proportions of a normal granite. The dark variety contains a relatively smaller amount of feldspar and quartz, with a larger amount of biotite and some hornblende. Origin, igneous.

Canterbury granite gneiss.—The formation consists essentially of a muscovite-biotite gneiss, varying in texture from a fine, even-grained rock to a porphyry with feldspars a quarter of an inch or so in length. Metamorphism has produced irregular wavy bands of biotite separated by flattened layers of quartz and feldspar. Origin, igneous.

Maromas granite gneiss.—It is in some places massive, but usually well foliated. Composition is that of a normal granite. (See Sterling granite gneiss.) This rock is eruptive and is intruded into the Bolton schist.

Haddam granite gneiss.—It is a light-colored, rather fine-grained, granitic aggregate of quartz and feldspar, through which are scattered small isolated flakes of biotite. In the outcrops the rock is a moderately thick-bedded gneiss. Origin, igneous.

Branford granite gneiss.—The rock is a medium-grained granite with a banded structure, consisting very largely of white feldspar. In the feldspars are embedded small round quartz grains, and biotite is also present in about equal amount. Small reddish garnets commonly occur, but may fail entirely. The rock has a pronounced tendency to weather, with a brownish stain on the cleavage surfaces of the feldspar. Origin, igneous.

Stony Creek granite gneiss.—See Sterling granite gneiss.

Lyme granite gneiss.—See Sterling granite gneiss.

New London granite gneiss.—See Sterling granite gneiss.

Mamacoke gneiss.—The rocks occupying the larger areas of this formation are decidedly gneissic, sometimes containing much biotite, and more rarely hornblende, and are frequently granitic in appearance. The typical rock is uniformly medium grained, light to dark gray in color, and consists of white feldspar and quartz, with brilliant black mica, and sometimes small amounts of hornblende and garnet. The dark minerals constitute about one-third of the rock, but the range in both directions is considerable, in one case giving rise to a biotite gneiss, in the other a granitic one. Origin, igneous.

NATURE AND AGE OF THE GRANITIC INTRUSIONS OF CONNECTICUT.

The stages of the process whereby the granite masses of Connecticut have attained their present form are not altogether understood. It is, however, certain, as stated above, that the granites and granite gneisses have been revealed by the removal of overlying material; and if we assume erosion to have proceeded much farther and an additional thousand feet or so to have been removed from the rocks of the State we should find that, instead of the limited areas of

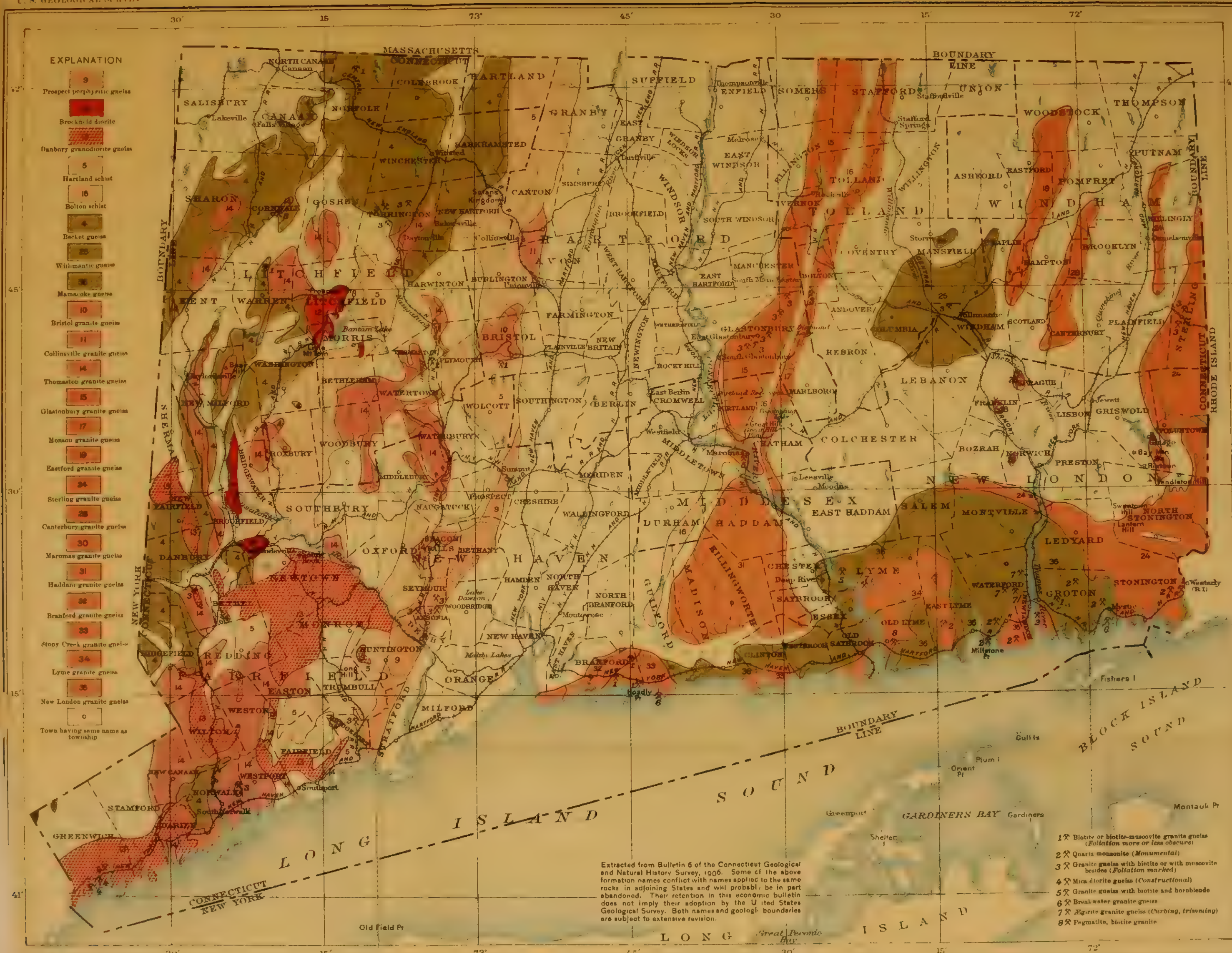
granite gneiss and the few patches of granite now exposed, large areas of granite surrounded by gneisses and schists would exist.

There are several ways in which molten rock may find its way into strata already existing. It may be actually forced into other rocks in such a way as to crowd them apart or to lift them bodily. On the other hand, the molten mass which later becomes granite may work its way quietly into the surrounding rock, melting and assimilating the overlying strata. This is believed to be the method of intrusion by which the Connecticut granites were formed, and a mass like the Stony Creek granite gneiss or the Sterling granite gneiss is to be considered as merely surface portions of igneous intrusions which extend to great depth. It is quite likely, as previously stated, that some of these granite areas represent deep-seated portions of volcanoes from which at one time granitic lavas were poured out over the State. If such lava flows ever existed all traces of them have been removed by the erosion of thousands of feet of rock.

The Bristol and Collinsville granite gneisses represent another type of intrusion. In both these localities the Hoosac (" Hartland ") schist is seen to lap up over the granitic rock, and the gneiss exposed shows evidence of being near the top of the original igneous mass.

It is generally supposed that the granites, and particularly the granite gneisses of Connecticut, date from the earliest geologic ages—that, in fact, they represent " parts of the original earth's crust," and this popular view coincides with the opinion expressed by geologists who have not studied the occurrence of these rocks in detail; but there is little to justify this view of the great age of most of the granitic rocks. With the possible exception of the Becket gneiss, no gneisses in Connecticut are regarded as of pre-Cambrian age, and the fact that the Sterling granite gneiss cuts metamorphosed Carboniferous sediments make it unnecessary to ascribe a date earlier than the Carboniferous for most of the intrusives in the eastern part of the State.

The last of the great earth movements that gave the structure to the metamorphic rocks of Connecticut occurred, presumably, at the close of Carboniferous time, and though the structure of some of the granite gneisses indicates that they have been subjected to more than one series of earth movements, the structure of others may be explained on the theory that they have passed through only one period of metamorphism. For example, the gneissoid character of the Sterling granite gneiss is believed to date from post-Carboniferous time. If this hypothesis is correct, the igneous gneisses are, in part at least, younger than the schists with which they are associated. The granites which are little or not at all metamorphosed are probably of two periods, the first coincident with the movements which produced the gneissoid and schistose structure in the rocks,



Base map adapted from map by H. E. Gregory and H. H. Robinson

A. HOEN & CO. BALTIMORE, MD.

PRELIMINARY GEOLOGIC AND ECONOMIC MAP OF CONNECTICUT

Scale $\frac{1}{500000}$

5 0 5 10 15 Miles

and the second at some later date. This second date of intrusion is proved by the fact that the massive granites have not been subjected to the pressure which produced the gneisses and that they cut into and through the granite gneisses. Occasionally, moreover, fragments of gneiss are included in the granite itself. The descriptions of Stony Creek granite gneiss and Westerly granite (pp. 377, 406, and 415) make this relationship clear. The relative age of the various granites and gneisses may be stated as follows: The granite gneisses intruded into the ancient sediments are the oldest. The less metamorphosed granites come next; the pegmatites were formed at the same time as the granites or at a slightly later date, and dikes of granite were intruded after most of the pegmatites were formed. For instance, part of the granite quarried at Westerly is intrusive in pegmatites, granite, and granite gneiss alike and appears to be the latest formed rock in southeastern Connecticut.

GRANITE QUARRIES OF CONNECTICUT.

The locations of the quarries are shown on the geologic map (Pl. XXVIII) by symbols.

FAIRFIELD COUNTY.

BRIDGEPORT.

The **Burlison or Parsons quarry** is in Bridgeport Township, on the Trumbull Road, about 750 feet south of the Trumbull line and about 3½ miles north-northeast of the Bridgeport railroad station. Owner, C. Lewis Bill, Park Gardens, Bridgeport. Quarry disused since 1913, but not abandoned.

The granite (specimen D, XXX, 40 a) is a muscovite-biotite granite gneiss of medium bluish-gray color and fine-grained gneissic texture, with finely laminated, unplicated foliation, its particles being under 0.2 inch. Its constituents, in descending order of abundance, are translucent bluish potash feldspar (microcline and orthoclase), clear colorless quartz, translucent bluish soda-lime feldspar (oligoclase-andesine), muscovite (white mica), and biotite (black mica). Accessory: Zircon, apatite. Secondary: White mica and calcite, but not enough to effervesce with muriatic-acid test.

Owing to its foliaceous texture the stone looks very different on its rift, grain, and hardway sides, and the muscovite gives its rift face a brilliant sheen.

The quarry measured in 1908 about 100 by 50 feet and 25 to 30 feet in depth.

Rock structure: The gneiss foliation strikes N. 30° E. and is vertical. The sheets, 6 inches to 3 feet thick, dip 25° NE. and are in places horizontal. There are three sets of joints—(a), strike N. 50° W., dip 40°–50° NE., spaced 3 to 40 feet; (b), strike N. 55° W., dip 60° SW., forms a heading at the north-northeast wall, one 50 feet south of it, and a third at the south-southwest wall; (c), strike about north, dip steep east, forms a heading on west side. The rift seems to correspond to the foliation (N. 30° E., vertical), the grain to be horizontal, and the hardway vertical, N. 50° W. Pegmatite occurs parallel to the foliation.

Transportation, by cart.

The product was used for cellars, walls, and trimmings, for which its even foliation well adopts it. Specimen: Trimmings of Bridgeport railway station.

DANBURY.

The **Treadwell prospect** is in Danbury Township, 1¾ miles north-northwest of the Danbury railroad station, on a ridge east of the Padanaram road, on the farm of Stephen B. Treadwell.

The granite is an unevenly banded fine-grained dark to medium pinkish gray biotite gneiss. It consists of pinkish and milk-white feldspar, smoky quartz, and black mica.

Stone has been quarried for underpinning, off and on for years, from small openings 250 and 500 feet east of the house.

Rock structure: The gneiss foliation strikes N. 45°–55° W. and dips 50° NE. to 90°. It is injected with pegmatite. The ledges are probably extensive, but concealed by a thin cover of gravel and clay.

GREENWICH.

The **Voorhis quarry** is in Greenwich Township at the head of Byram Harbor, a mile southwest of the Greenwich railroad station. (See map, fig. 85.) Quarry abandoned since 1908.

The "Greenwich" blue-black granite (specimen D, XXX, 43, a) is a mica diorite gneiss of extremely dark bluish-gray color (darker than "Quincy extra dark") and of coarse porphyritic gneissic textu e, with feldspars, mostly twins, forming lenses up to 2 by 0.4 inch, but mostly not over 1 by 0.3 inch, and down to 0.3 by 0.1 inch. The long axes of these lenses are parallel to the rock foliation and the plane between the twin crystals is nearly so. The constituents of the rock, named in descending order of abundance, are medium translucent bluish-gray soda-lime feldspar (andesine, with possibly oligoclase-andesine), some in large twins, a little micacized and kaolinized; biotite (black mica); clear colorless potash feldspar (microcline); clear colorless quartz; and green hornblende. Accessory: Pyrite, titanite, apatite, allanite, zircon; the three first in some abundance. Secondary: Epidote, kaolin, a white mica, calcite. The rock effervesces slightly with muriatic-acid test.

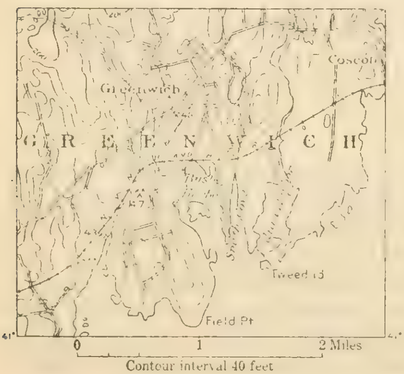


FIGURE 85.—Map of part of Greenwich, Conn., showing location of granite (diorite gneiss) quarries. 42, Ritch; 43, Voorhis; 47, Christiano, Oak Ridge; 48, Christiano, Hamilton Avenue.

Two tests of the ultimate transverse strength of this granite made at the United States arsenal at Watertown, Mass., in November, 1896, on pieces 15 inches long between supports, yielded these results:

Results of transverse tests of "Greenwich" blue-black granite and Quincy granite.

	Test No.	Breadth.	Depth.	Breaking weight.	Modulus of rupture.
		Inches.	*Inches.*	*Pounds.*	*Pounds.*
Greenwich	9762	1.01	1.02	152	[a] 3,257
Do.	9763	1.02	1.02	177	[a] 3,757
Quincy	9765	1.01	1.02	177	2,164

[a] Average modulus of rupture of Greenwich granite, 3,507 pounds.

The rock is exceedingly tough under the hammer. It is dark yet brilliant, and the contrasts between its black mica and bluish-gray feldspars are very marked and pleasing. Its apparent texture and shade differ on its three sides. The side parallel to the foliation, showing hardly any feldspar, is black; the side at right angles to the foliation and parallel to the long axes of the lenses shows the feldspar most conspicuously; and the side transverse to those axes shows the light and dark minerals more evenly mixed. A structure built of the stone set on the edge of its foliation would be almost black. Its appearance would differ somewhat according as the grain face or the hard-way face were alone exposed, and if the stones were laid promiscuously, without regard to texture, the effect would be still different.

The quarry, opened before 1833, measured in 1908 about 500 feet from north to south by 200 feet across and 50 feet in depth.

Rock structure: The gneiss foliation strikes N. 15°–20° E. and is vertical. The sheets, 1 to 35 feet thick, strike N. 80° W., dip 20° S., and are mostly separated by small aplite dikes. One set of joints only; strike N. 65° W., dip vertical or very steep and slickensided. The rift is reported as parallel to the foliation; the grain as vertical, with N. 80° W. course; and the hardway horizontal. Small dikes of aplite (described on p. 44) run parallel to the foliation and also undulate horizontally.

Transportation, by cart 500 feet to a wharf admitting schooners of 6½ feet draft at high tide.

The product was used for buildings and massive structures, and the waste for riprap. Specimens: Fort Schuyler, Throgs Neck, Long Island Sound; physicians' quarters at south end of Blackwells Island, East River; Episcopal Church, Port Washington, Long Island; residence of C. J. Osborn, Mamaroneck, N. Y.; wall about Trinity Cemetery, One hundred and fifty-third Street and Broadway, New York City.

The **Ritch quarry** is in Greenwich Township, on the west side of Byram Harbor, 1¼ miles southwest of Greenwich railroad station. (See map, fig. 85, p. 362.) Operators, W. & S. Ritch, Port Chester, N. Y. Quarry abandoned.

The granite (specimens D, XXX, 42, a, b), "Greenwich" blue-black granite, is a mica diorite gneiss of extremely dark bluish-gray color and coarse porphyritic gneissic texture identical with that of the Voorhis quarry, described above.

The quarry in 1908 was about 200 feet square, with working faces 15–40 feet high on the north, south, and west.

Rock structure: The gneiss foliation strikes N. 20° E. and dips 90°. The sheets, 2 to 3 feet thick and generally separated by thin aplite dikes, dip 25° W. There are two sets of joints—(*a*), strike N. 80° W., vertical, spaced 2 to 10 feet, forms the north and south walls and two headings near the center; (*b*), strike N. 15°–20° W., vertical, spaced 10 feet or more. The rift is reported as parallel to the foliation, the grain vertical with N. 80° W. course, and the hardway horizontal. Pegmatite dikes, mostly of feldspar, the largest 16 inches thick, meander vertically along the foliation. Dikes of aplite, 0.25 inch to 2 inches thick (specimen D, XXX, 42, c), are of medium bluish-gray color and very fine texture with particles under 0.1 inch. (See for details p. 44.) This aplite differs from the gneiss only in its poverty of mica and richness of quartz. Rusty stain is an inch thick on sheet and joint faces.

Transportation, by cart 500 feet to wharf admitting schooners of 7 feet draft at high tide.

The product is used for buildings and street work and the waste for riprap. Specimens: Catholic churches in Flushing and Mamaroneck, N. Y., and Stam-

ford, Conn.; Catholic cathedral and bishop house at intersection of Vanderbilt, Lafayette, Clermont, and Green avenues, Brooklyn.

The **Christiano Oak Ridge quarry** is in Greenwich Township at the north end of the ridge between Bush and Byram harbors, about three-fifths mile west-southwest of the Greenwich railroad station. (See fig. 85.) Operator, Joseph Christiano, Greenwich. Quarry abandoned.

The granite (specimen D, XXX, 47, a), "Greenwich" blue-black granite, is an extremely dark bluish-gray mica diorite gneiss, identical with that of the Voorhis quarry, described on page 362, except that it has a little augite besides the hornblende.

The quarry, opened in 1901, measured in 1908 about 175 by 150 feet and from 10 to 20 feet deep.

Rock structure: The gneiss foliation strikes N. 15°–20° E. and dips 90°. The sheets, 2 to 10 feet thick, are horizontal or dip very low east. There are four sets of joints—(*a*), strike N. 75° W., vertical, spaced 1–10 feet; (*b*), strike N. 20° E., vertical or steep west, spaced 3–10 feet, coinciding with the small aplite dikes; (*c*), strike N. 30° W., vertical (exceptional), spaced as low as 5 feet; (*d*) (one only), strike N. 85° W., dip 55° about north. Pegmatite dikes, in beadlike lenses up to 8 inches thick, are either parallel to the foliation or branch from it. The numerous aplitic dikes, from 0.25 to 3 inches thick, strike with the foliation but have plications from 1 to 6 feet across. This aplite (specimen D, XXX, 47, b) is of very light gray color and very fine texture, and is almost identical with specimen 42, c, from the Ritch quarry, described on page 44.

Transportation, by cart.

The product is used for buildings, and the waste is crushed for roads. Specimen buildings: Catholic Church, Bruce Memorial gate (Bruce Park, Greenwich Avenue and Steamboat Road), and residence of Charles Hirshhorn North Street, Greenwich.

The **Christiano Hamilton Avenue quarry** is in Greenwich Township, half a mile northwest of the Greenwich railroad station. (See fig. 85, p. 362.) Operator, Joseph Christiano, Greenwich. Quarry abandoned.

The granite (specimen D, XXX, 48, a), "Greenwich" blue-black granite, is a mica diorite gneiss of extremely dark bluish-gray color identical with that of the Voorhis quarry, described on page 362.

The quarry, opened in 1873, measured in 1908 about 60 by 30 feet and from 10 to 20 feet deep.

Rock structure: The gneiss foliation strikes N. 15° E. and is about vertical. Sheets are hardly developed. There are two sets of joints—(a), strike N. 45° W., vertical, spaced 8 to 15 feet; (b), loose, strike N. 15° E., vertical, spaced 10 feet. The rift is reported as parallel to the foliation, the grain at right angles to it and vertical, and the hard way horizontal.

Transportation, by cart.

The product is used for buildings. Specimens: Residences of George E. Weed, Rockside Park, and of James McCutcheon, Belle Haven Park, Greenwich.

NORWALK.

The **Hall quarry** (formerly known as the Bates quarry) is in Norwalk Township, about 1½ miles northeast of the Norwalk railroad station. Operator, Irving Hall, Norwalk.

The granite (specimen D, XXX, 44, a) is a muscovite-biotite granite gneiss of light warm-gray color and of gneissic medium inclining to fine texture, with feldspars and mica to 0.25 inch. It is brightly spangled with mica on its

foliation face. Its constituents, named in descending order of abundance, are light cream-colored potash feldspar (microcline), but little kaolinized; pale smoky quartz, with cavities in sheets; milk-white soda-lime feldspar (oligoclase albite), much kaolinized, micacized, and with calcite; muscovite (white mica); and biotite (black mica). Accessory: Garnet, apatite. Secondary: Kaolin, a white mica, calcite, some in veinlets. Effervesces freely in places with muriatic-acid test.

The quarry in 1908 was about 50 feet square and from 20 to 30 feet deep.

Rock structure: The gneiss foliation dips 5° to 20° NW. The sheets, 1 to 4 feet thick, parallel to the foliation, are but imperfectly developed. There are two sets of joints—(a), strike N. 40° E., vertical, forms the north wall; (b), strike northwest, vertical, spaced 2 to 8 feet, forms the east and west walls and a heading 8 feet wide near the north wall. Some of the joints of this heading have been parted 0.25 to 2 inches and filled with quartz. Both sets of joints are slickensided. The rift is along the foliation.

Transportation, by cart.

The product is used for walls, underpinning, steps, etc. The quarry is worked only occasionally.

HARTFORD COUNTY.

BRISTOL.

The **Dunn quarry** is on Divinity Street, in Bristol, about a mile west-southwest of the center of the borough. Quarry no longer operated.

The granite (specimen D, XXX, 62, a, "Bristol granite gneiss," No. 10 of the State preliminary geologic map) is a garnetiferous quartz monzonite gneiss of light, including to medium bluish-gray color and of gneissic banded fine texture, with feldspars up to 0.2 inch, mica to 0.1 inch, and garnets to 0.08 inch. It has wavy bands and lenses of light and dark and reddish color, the light bands up to 0.5 inch in width, the dark to 0.3 inch, and the reddish to 0.1 inch. Its constituents, in descending order of abundance, are clear to whitish soda-lime feldspar (albite), some of it slightly kaolinized; clear bluish quartz, with cavities in sheets; a little potash feldspar (orthoclase); biotite (black mica), some of it chloritized. Accessory: Garnets (fourth or fifth in order of abundance), magnetite, apatite. Secondary: Kaolin, chlorite, limonite.

This is a hard, serviceable, and attractive stone.

The quarry consists of two openings, one about 100 by 50 feet and 5 to 10 feet deep, the other 50 feet square, barely opened in 1909.

Rock structure: The gneiss foliation strikes east and dips steeply south. The sheets, 3 to 8 feet thick, are irregular. There are three sets of joints—(a), strike about north, with headings 12 feet wide; (b), strike about east; (c), diagonal. The spacing of joints in the smaller opening admits the quarrying of blocks 10 feet square by 3 to 5 feet. The rift in both openings is across the foliation.

Transportation, by cart 1 mile to railroad.

The product was used for foundations and buildings. "Brightwood," Mrs. W. A. McKay's mansion on West Street, in Bristol, was built of this granite, but some of it came from another now disused quarry, and some from the site of the mansion itself.

The **Seymour Street quarry**, in Bristol, is operated occasionally by the Pierson Engineering & Construction Co., Bristol.

The granite is like that of the Dunn quarry; the opening is small and irregular.

GLASTONBURY.

The **Glastonbury quarries,** as shown on the map (fig. 86), are scattered along a S. 48° W. ridge, the northern part of which is now known as Minnechaug Mountain, called also locally Birch Mountain, and the southern part of which goes by the name of Eightmile Hill. The gneiss foliation at the quarries strikes N. 45°–80° E., averaging about N. 60° E., and thus differs but little from the trend of the ridge. The strike at the Curtis quarry, however, is about north. The Peterson quarry, in Bolton, Tolland County (p. 399), is on the northeastern continuation of the same ridge. The strike there is N. 10° E.

FIGURE 86.—Map of Glastonbury, Conn., showing location of granite gneiss quarries. 32, Corbin; 33, Gorman; 34, Danielson; 35, Belden; 36, Curtis; 37, Brooks; 38, Slater; 39, Glastonbury Granite Works.

The rock at these quarries is a more or less obscurely porphyritic biotite granite gneiss, with feeble mineral contrasts and a marked foliation, but its texture and shade vary slightly at different quarries. It is designated on the State preliminary geologic map "Glastonbury granite gneiss, No. 15." The Glastonbury quarries have long supplied curbing and crosswalks to the city of Hartford, for which the foliation of the stone admirably adapts it.

The **Corbin quarry** is in Glastonbury, at the top of Birch Mountain, 5 miles east-northeast of Glastonbury village. (See fig. 86.) Operator, A. S. Freeburg, Hartford.

The granite (specimen D, XXX, 32, a) is a biotite granite gneiss of medium-gray shade and of fine gneissic texture, with porphyritic feldspars up to 0.3 inch, and matrix with particles under 0.05 inch. In places it has minute brown-

ish stain. Its constituents, in descending order of abundance, are cream-colored to milk-white potash feldspar (microcline and orthoclase), somewhat kaolinized; clear colorless quartz; clear to translucent colorless soda-lime feldspar (oligoclase); and biotite (black mica), some of it chloritized, with a little muscovite or bleached biotite. Both feldspars are intergrown with quartz more or less circular in cross section. Accessory: Epidote,[58] apatite, allanite, titanite. Secondary: Kaolin, limonite proceeding from allanite and producing the brown spots referred to, chlorite. No effervescence with muriatic-acid test.

The quarry is a small, irregular opening, begun in 1905.

Rock structure: Gneiss foliation and rift dip about 10° N. 50° W. The sheets, up to 3 feet thick, are horizontal or dip low N. 50° W. Pegmatite dikes are up to 4 inches thick.

Transportation, by cart 12 miles to Hartford.

The product is used entirely for curbing and circulars.

The **Glastonbury Granite Works quarries** are in Glastonbury Township, on Hebron Avenue, close to the village of Buckingham, 4½ miles east of Glastonbury village. (See fig. 86.) Operator, Glastonbury Granite Works (Inc.), Glastonbury.

The granite (specimen D, XXX, 39, a) is a biotite granite gneiss of medium, inclining to dark gray shade (thus darker than the Corbin quarry stone), and of fine gneissic texture, with porphyritic feldspars, the largest 0.3 inch, and matrix with particles under 0.1 inch. Its constituents, named in descending order of abundance, are cream-colored potash feldspar (microcline, somewhat kaolinized, and orthoclase); medium smoky quartz; whitish soda-lime feldspar (oligoclase to oligoclase-andesine), slightly micacized, some of it intergrown with quartz more or less circular in cross section; biotite (black mica), some of it chloritized, and a little muscovite or bleached biotite. Accessory: Epidote, titanite, allanite, apatite, zircon. Secondary: Kaolin, chlorite, a white mica, limonite stain, hematite. No effervescence with muriatic-acid test.

The first quarry, opened in 1908, was about 40 feet square by 20 feet deep. Since then an opening has been made on the west and still another on the southeast.

Rock structure: Gneiss foliation and rift strike N. 80° E. and dip 25° N. The sheets, 10 feet thick, dip with the foliation. The grain and hard way are equal.

Transportation, by cart 10 miles to Hartford.

The product is used for curbing, crosswalks, and steps.

The **Gorman quarry** is in Glastonbury, at the foot of Birch Mountain, a little south of the Manchester line, about 5¾ miles east-northeast of Glastonbury village. (See fig. 86, location approximate.) It is now disused.

The granite (specimen D, XXX, 33, (a), is a biotite granite gneiss of medium, very slightly bluish gray color, and of fine gneissic texture, with porphyritic feldspars to 0.3 inch in a matrix with particles under 0.1 inch, in a thin section mostly from 0.11 to 0.39 millimeter. Its constituents, in descending order of abundance, are milk-white potash feldspar (microcline, kaolinized, and orthoclase); pale smoky quartz showing effects of strain and with some cavities; translucent whitish soda-lime feldspar (oligoclase); biotite (black mica); and a little muscovite or bleached biotite. Accessory: Epidote, magnetite, apatite, garnet, allanite. Secondary: Kaolin, limonite stain. Both

[58] Rice and Gregory regarded the epidote as probably of primary origin. See their Manual of the geology of Connecticut, 1906: Connecticut Geol. and Nat. Hist. Survey Bull. 6, p. 118. Some of it forms rims about allanite.

feldspars are intergrown with quartz circular in cross section. No effervescence with muriatic-acid test.

This stone is less weathered than that of the last two quarries, and therefore harder. It has been used for buildings, steps, etc.

The **Danielson quarry** is in Glastonbury Township, on the south side of the top of Eightmile Hill, 3½ miles southeast of Glastonbury village. (See fig. 86.) It is now disused.

The granite (specimen D, XXX, 34, a) is a biotite granite gneiss of dark, inclining to medium brownish-gray color and of fine marked gneissic texture, with porphyritic feldspars to 0.3 inch in a matrix with particles under 0.1 inch, in thin section mostly between 0.11 and 0.84 millimeter. Its constituents, in descending order of abundance, are pale-buff to pinkish potash feldspar (microcline and orthoclase), somewhat kaolinized; medium smoky quartz showing effects of strain and with some cavities in sheets; grayish translucent soda-lime feldspar (oligoclase), slightly kaolinized; and biotite (black mica). Accessory: Epidote (fifth in order of abundance), apatite, magnetite, allanite. Secondary: Kaolin, limonite, hematite (stain). No effervescence with muriatic-acid test.

The quarry measured, in 1908, about 60 by 35 feet and 10 feet deep.

Rock structure: Gneiss foliation and rift strike N. 55° E. and dip 25° N. The sheets, 1 to 2 feet thick, are also parallel to these. There is one joint on the north side, striking N. 70° E. Vertical pegmatite dikes, 3 to 6 inches thick, strike N. 80° W. Some of smoky quartz up to 4 inches thick.

Transportation, by cart 10 miles to Hartford.

The product was used for curbing and steps.

The **Belden quarry** is in Glastonbury Township, on Eightmile Hill, 0.3 mile south of the Hartford turnpike and 3 miles southeast of Glastonbury village. (See fig. 86.) Operator, H. T. Lingner, East Glastonbury.

The granite (specimen D, XXX, 35, a) is a biotite granite gneiss of medium buff-gray color (a trifle lighter than "Concord granite") and of fine gneissic texture, with feldspars to 0.2 inch and mica, in aggregates, up to 0.5 inch, conspicuous along the foliation. Porphyritic texture not apparent. Its constituents, in descending order of abundance, are cream-colored potash feldspar (microcline and orthoclase), somewhat kaolinized; pale smoky quartz, some of it in long laminae 0.28 millimeter wide; whitish soda-lime feldspar (oligoclase), somewhat kaolinized; biotite (black mica); and a little muscovite or bleached biotite. Accessory: Garnet (fifth in order of abundance), epidote, magnetite, allanite. Secondary: Kaolin, limonite stain, calcite. No effervescence with muriatic-acid test.

The quarry consists of several openings, some of which were made in 1863. The one worked in 1908 measured 50 by 40 feet and 20 feet deep.

Rock structure: Gneiss foliation and rift strike northeast and dip 10° to 20° NW. The sheets, 6 inches to 5 feet thick, are parallel to these. There are two sets of joints—(a), strike N. 20° E., vertical, forms the north wall; (b), strike N. 65° W., vertical, forms the east and west walls and recurs in center, discontinuous. The grain is reported as vertical, with north-south course. Pegmatite dikes are up to 6 inches thick. Some smoky quartz veins or lenses.

Transportation, by cart 10 miles to Hartford.

The product is chiefly used for curbing and crosswalks, and smaller blocks for paving. Blocks 1½ to 2 inches thick are prepared for lining tubes at feldspar-crushing works instead of the oak timber formerly used for that purpose.

The **Brooks quarry** is in Glastonbury Township, on the northeast side of Eightmile Hill, 3½ miles east-southeast of Glastonbury village. (See fig. 86.) Operator, Henry R. Brooks, R. D., Glastonbury.

The granite is a biotite granite gneiss of medium-gray shade and fine gneissic porphyritic texture, identical in composition with that of the Corbin quarry, described on page 366, and with the same minute brown spots, due to allanite.

The quarry, opened in 1889, measured in 1908 about 400 feet from east to west by 150 feet across at one end and 50 feet at the other, and from 5 to 60 feet deep.

Rock structure: The gneiss foliation and rift strike N. 70° E. and dip 25° N. 20° W. The sheets, 1 to 6 feet thick, are parallel to these. There are two sets of joints—(a), strike N. 75° E., dip steep S. 15° E., spaced 10 to 20 feet; (b), strike N. 35° W., vertical, spaced 20 feet. The grain is vertical, north to south, but the stone breaks with equal facility along the hard way. Four vertical pegmatite dikes, the largest 10 inches thick, strike N. 77° W. and are 10 feet or more apart. This pegmatite (specimen D, XXX, 37, b) consists of cream-colored feldspar and smoky quartz, with sparse minute garnets and rare scales of biotite and muscovite.

Transportation, by cart 10 miles to Hartford, or 5½ miles to rail at South Manchester, or 5 miles to wharf at Naubuc (Glastonbury landing), on the Connecticut.

The product is used for curbing and building.

Specimens: Curbing and steps, Cheney Park, South Manchester, and trimmings on Methodist Church at Windsor.

The **Slater quarry** is in Glastonbury Township, one-fourth mile west-southwest of the Brooks quarry and about 3¾ miles southeast of Glastonbury village. (See fig. 86.) Quarry now disused.

The granite is a biotite granite gneiss, identical with that of the Corbin quarry described on page 366.

The quarry was in 1908 20 feet square and 15 feet deep.

Rock structure: Gneiss foliation and rift strike N. 55° E. and dip 30° N. 35° W. The sheets, 2 to 4 feet thick, are parallel to these. There are two sets of joints—(a), strike northeast, dip 40° SE., spaced 15 feet; (b) strike northwest, vertical, one only. The grain is vertical, north to south, but the rock breaks equally well along the hard way. Four-inch pegmatite dikes strike N. 70° W. A 12-inch vertical dike strikes N. 10° E., carries muscovite in plates up to 5 inches square and 4 inches thick, about 6 inches apart, the rest of the dike being mostly feldspar.

The product was used for curbing, crosswalks, and steps.

LITCHFIELD COUNTY.

CORNWALL.

The **Benedict quarry** is in Cornwall Township, on the north side of White Rock, three-fourths mile east of Cornwall village. Owner, Trusten H. Benedict. Quarry disused.

The granite (specimens D, XXX, 60, a, b, c), is a biotite-muscovite granite gneiss of medium bluish-gray color and of medium, inclining to fine gneissic texture, with feldspars to 0.3 inch and mica to 0.1 inch; also with rare porphyritic clear feldspars, the largest 0.4 inch. Its constituents, in descending order of abundance, are clear bluish potash feldspar (microcline and orthoclase), intergrown with quartz that is circular in cross section; clear colorless quartz; translucent to milk-white soda-lime feldspar (oligoclase), somewhat kaolinized and with calcite; biotite (black mica); and muscovite (white mica).

Accessory: Illmenite (probably) surrounded by titanite, apatite, allanite, zircon. Secondary: Calcite, epidote, kaolin, a white mica. There is a little minute vermicular intergrowth of quartz and feldspar and some granulation of the feldspars. Slight effervescence with muriatic-acid test.

This is a bright-bluish foliaceous stone, without marked mineral contrasts.

The quarry is 75 feet square by 10 to 15 feet deep.

Rock structure: Gneiss foliation and rift strike N. 50° E. and are vertical. The sheets, 2 to 4 feet thick, dip low northwest. There are two sets of joints—(a), strike N. 60°–75° W., vertical, spaced 20 to 25 feet, forms a heading on the south wall; (b), strike N. 10° E., vertical, spaced 15 feet. The grain is vertical, with northwest course. Pegmatite dikes up to 2 inches thick strike N. 15° E. Between the quarry and the cemetery on the north side of the road a similar gneiss is in contact with, or contains an inclusion of, a fine-grained biotite gneiss with particles up to 1 millimeter, consisting of quartz, biotite, microcline, and oligoclase-andesine, with accessory apatite, titanite, zircon, and striking N. 10°–20° E.

Transportation, by cart 4½ miles to rail at Cornwall Bridge.

The product was used for trimmings, for which its foliation and color well adapt it.

LITCHFIELD.

The **Mascetti quarry**, 2½ miles south of Torrington, is in the township of Litchfield, three-fourths mile northwest of East Litchfield village, on the west side and south end of a knoll rising 480 feet above the village. Operators, Mascetti & Holley, Torrington. Idle since 1918.

The granite (specimen D, XXX, 53, a) is a muscovite-biotite granite gneiss of medium, inclining to light bluish-gray color and of fine gneissic texture, with feldspars under 0.2 inch and mica mostly under 0.1 inch. Its constituents, named in descending order of abundance, are clear bluish potash feldspar (microcline); light smoky quartz with cavities; milk-white soda-lime feldspar (oligoclase), somewhat kaolinized and intergrown with quartz, circular in cross section; muscovite (white mica); and biotite (black mica) in smaller flakes, some of it chloritized. Accessory: Garnet (sixth in order of abundance), tourmaline, apatite, zircon. Secondary: Kaolin, calcite, chlorite. The rock effervesces slightly with muriatic-acid test.

This rock is brilliant, with muscovite on its foliation face.

The quarry, opened about 1903, was in 1908 about 200 feet long, with a working face 50 feet high on the east.

Rock structure: Gneiss foliation and rift strike N. 20° E. and dip 20°. The sheets, 2 to 4 feet thick, dip 20° to 50° NW. One set of joints only, strike N. 5° E., dip 65° E., spaced 3 to 20 feet and over. Pegmatite dikes, with black tourmaline and bordered with aplite, 1 to 2 feet thick, meander vertically with a N. 15° E. course. Others up to an inch thick are parallel to the foliation.

Transportation, by cart 1¾ miles to East Litchfield, or 2½ miles to Torrington.

The product is used for curbing and steps, for which it is well adapted.

NORFOLK.

The **Crissey quarry** is in Norfolk Township, on the southeast side of Bald Mountain, 2⅞ miles north-northwest of the village of Norfolk. Owner, R. I. Crissey, Norfolk.

The granite (specimen D, XXX, 61, a, b,) is a biotite-muscovite granite gneiss of medium, very slightly greenish gray color and of even-grained, fine, obscurely gneissic texture, with feldspars under 0.2 inch and mica under 0.1

inch. Its constituents, in descending order of abundance, are clear colorless potash feldspar (microcline and orthoclase); clear colorless quartz, with some cavities in sheets; milk-white soda-lime feldspar (oligoclase), mostly kaolinized, micacized, and with calcite; biotite (black mica), some of it chloritized; and muscovite (white mica). Accessory: Magnetite, apatite, allanite (rimmed with epidote), zircon. Secondary: Kaolin, calcite, a white mica, epidote, limonite stain. There is some feldspar granulation and also vermicular intergrowth of quartz and feldspar.

The stone effervesces with muriatic-acid test. R. C. Wells, a chemist of this Survey, finds that it contains 0.36 per cent of CaO (lime), soluble in warm dilute (10 per cent) acetic acid, which indicates a content of 0.64 per cent of $CaCO_3$ (calcium carbonate, calcite).

This is a bright, fine-grained gray granite, without mineral contrasts and without contrasts of tint between cut and polished faces.

The quarry, opened before 1880, consists of four excavations, the highest and largest of which measures about 150 feet from southeast to northwest and has a working face 50 feet high on the northeast.

Rock structure: The sheets, 6 inches to 5 feet thick (some reported as 7 feet but now covered), dip 10° NW. and are normal. There are two sets of joints—(a), strike N. 80° E., dip steep south to 90°, forms the northwest and southeast walls; (b), strike N. 20° E., vertical, discontinuous, spaced 5 feet or more. The rift is reported as about horizontal, but the rock splits southeast-northwest.

Transportation, by cart 1 mile to Central New England Railway.

The product was used for buildings, monuments, and coping. Specimens: Chapel of Congregational Church and the railroad station at Norfolk; Egbert T. Butler and Anson Gaylord monuments, Norfolk Center Cemetery.

This quarry, originally opened for coping for the Hoosac Tunnel, in Massachusetts, was closed in 1893, owing to a difficulty with the railroad as to freight rates.

ROXBURY.

The Rockside quarry is in Roxbury Township, on the east side of Mine Hill, four-fifths mile north of Roxbury station. Although this quarry is disused it is described on account of its geologic interest and its former economic importance.

The granite (specimen D, XXX, 57, a) is a muscovite-biotite granite gneiss of medium bluish-gray color and of fine-grained, even, unplicated gneissic texture, with particles under 0.2 inch and conspicuous white mica along its foliation.[69] In thin section the particles, aside from muscovite, range from 0.11 to about 2 millimeters. Its constituents, in descending order of abundance, are translucent bluish potash feldspar (mostly microcline with some orthoclase), slightly kaolinized; clear colorless quartz with cavities in sheets, one conspicuous set with cracks parallel to it, another less abundant at right angles to the first; muscovite (white mica); whitish soda-lime feldspar (oligoclase); the stone of an upper opening shows oligoclase to oligoclase-andesine), somewhat kaolinized and micacized; and biotite (black mica). Accessory: Apatite (rather abundant), zircon. Secondary: Kaolin, one or two white micas, calcite. No effervescence with muriatic-acid test.

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[69] W. H. Hobbs regards the muscovite as secondary and formed at the time of the foliation. He also describes the feldspar as crushed and granulated. See Rice, W. N., and Gregory, H. E., Connecticut Geol. and Nat. Hist. Survey Bull. 6, p. 110.

The quarry, opened in 1890, measured in 1908 about 800 feet from northeast to southwest by 275 feet across, with a working face on the northwest side 35 to 75 feet high.

Rock structure: The gneiss foliation dips gently southeast on the outer east side of the quarry but 15° S. 20° W. at the working face, tending to become horizontal within the hill. The sheets, 4 inches to 18 feet thick, correspond to the foliation. The upper 30 feet of the working face consists of thin sheets. There are two sets of joints. Set (a), strike northwest, vertical, forms a heading at the southwest wall; another, 6 to 8 feet wide, is 200 feet northeast of that wall; and another, 3 feet wide, is 300 feet farther northeast. The rock left unquarried about these two headings is about 50 feet wide. These joints are spaced 2 to 20 feet. Set (b), strike northeast, dips 7° NW., one 50 feet below the rock surface, another 25 feet lower. The rift corresponds to the foliation. The grain is reported as striking N. 35° E. and dipping 85° S. 55° E., and the hardway as vertical, with N. 55° W. course. There are white aplitic dikes, from 0.12 to 8 inches thick, almost parallel to the foliation. These are very quartzose, without biotite, and with rare muscovite. Some of this aplite is very light gray to white and of even-grained, very fine granitic texture, with feldspar and light smoky quartz under 0.1 inch and the finer particles between 0.05 and 0.56 millimeter. It effervesces with muriatic-acid test. Some of these dikes have oligoclase-albite and microcline in about equal parts. Smoky quartz veins, the largest 0.25 inch thick, run parallel to them. Others have a gneissic texture and show a little muscovite, evidently secondary and forming "membranes covering the foliation planes," as described by Hobbs. The main gneiss is also crossed by dikes of rose-colored aplite up to 4 feet thick, dipping like the joints of set (b). One of these consists chiefly of oligoclase-andesine with crush borders, smoky to amethystine quartz, a little microcline, and rare muscovite but no biotite, in places with microscopic garnets. All its particles are under 0.1 inch. One of the smaller dikes contains microcline, quartz, a little albite, garnet, muscovite, apatite, named in descending order of abundance. Its feldspars are under 0.05 inch and its quartz particles up to 0.2 inch.

Within three of the headings are the mineral veins described on page 75, evidently all related to the larger siderite vein which was formerly mined on the hill and to which it owes its name. Away from the headings the gneiss has little if any rusty stain.

Transportation, by siding to Litchfield branch of New York, New Haven & Hartford Railroad.

The product was used for buildings and railroad bridges, and the waste blocks, with aplite or other blemishes, for retaining walls. The stone was in demand because of its color and low price. Specimens: Four rock-faced houses, corner Seventy-second Street and Tenth Avenue, and the retaining wall of the New York Central & Hudson River Railroad, Sixty-seventh to Seventy-second Streets, New York. This wall is 1,350 feet long, 58 feet high; base 21 feet wide on Seventy-second Street.

THOMASTON.

The **Plymouth quarry** is in Thomaston Township, about 1½ miles south of Thomaston village and nearly half a mile north of Reynolds Bridge. Operator, Plymouth Granite Co., Thomaston.

The granite (specimen D, XXX, 54, a) is a quartz monzonite of medium bluish-gray color and of even-grained, fine granitic texture, with feldspars and mica up to 0.1 inch. Its constituents, in descending order of abundance, are light smoky quartz, with hairlike crystals of rutile and cavities in sheets;

translucent bluish soda-lime feldspar (oligoclase), some of it micacized and kaolinized; clear colorless potash feldspar (microcline and orthoclase); biotite (black mica); and muscovite (white mica). Both feldspars are intergrown with quartz more or less circular in cross section. Accessory: Apatite, rutile. Secondary: Kaolin, a white mica. No effervescence with muriatic-acid test.

This is a bright fine-grained monumental granite which is without mineral contrasts but which cuts and hammers light. Newberry,[60] in 1884, referred to the adaptation of this stone to monumental work.

The quarry measured in 1908 about 200 feet from north to south by 50 feet across, with a working face 20 to 40 feet high on the east.

Rock structure: The granite is capped by 10 to 20 feet of quartz monzonite gneiss, gray or consisting of white feldspar and quartz bands, 0.2 to 0.3 inch wide, alternating with black bands of biotite less than 0.05 inch wide. The constituents of this gneiss, in descending order of abundance, are light smoky quartz with cavities, milk-white oligoclase, whitish orthoclase, biotite, and a little muscovite or bleached biotite. Accessory: Magnetite, apatite, titanite. Secondary: Kaolin, a white mica. This gneiss is intricately plicated. In places its foliation is abruptly intersected by the granite. The boundary between the two rocks is very irregular, and pegmatite occurs along part of it. A tapering inclusion of the gneiss, 10 feet by 14 inches or more long and 3 feet wide, occurs 8 feet below the contact. The sheets, 6 inches to 3 feet thick, dip gently west but are less regular in the gneiss capping. There are two sets of joints—(a), strike N. 35° E., vertical, spaced 8 to 30 feet, continuing into the gneiss; (b), strike N. 80° W., vertical, spaced 3 to 10 feet or over.

Transportation, by very short siding to New York, New Haven & Hartford Railroad.

The product is used for monuments.

TORRINGTON.

The **Costello quarry** is in Torrington Township, 2½ miles northwest of Torrington and 550 feet above it. Operator, Edward M. Costello, R. D. 1, Torrington. Idle since 1916.

The granite (specimen D, XXX, 50, a) is a muscovite-biotite granite gneiss of medium faintly buff gray color and of fine, very gneissic texture, with feldspars under 0.2 inch, but with larger micas conspicuous on the foliation face and with sparse garnets to 0.2 inch. Its constituents, in descending order of abundance, are cream-colored potash feldspar (microcline), intergrown with quartz that is more or less circular in cross section; light smoky quartz with cavities in sheets; cream-colored soda-lime feldspar (oligoclase-albite to albite); muscovite (white mica); and biotite (black mica). Accessory: Garnet, apatite. Secondary: Limonite.

The quarry, opened in 1898, measured in 1908 about 250 feet in a N. 60° E. direction by 50 feet across and 25 feet in depth.

Rock structure: The foliation strikes N. 50° E. and dips 55° N. 40° W. The sheets, from 8 to 12 feet thick (exceptionally, near the surface, 1 foot thick), are horizontal or inclined to 30° NNW. There are two sets of joints—(a), strike N. 30° E., dip 30°–70° N. 60° W., spaced 8 to 10 feet; (b), strike N. 20° W., dip 70° N. 70° E, spaced over 100 feet, forms a heading at the west end. The rift corresponds to the foliation, and there is little difference between the grain and the hard way. Garnetiferous pegmatite dikes are up to 2 inches thick. There is little or no rusty stain on sheet surfaces.

[60] Tenth Census, vol. 10, p. 321, 1884.

Transportation, by cart 3 miles to Torrington or 11 miles to Winsted.

The product is used for building, trimming, and curbing. Specimens: Parish house of Third Congregational Church, Torrington; Winsted Hosiery Co.'s office, Winsted; trimmings on public library, Winsted; trimmings on factories of Standard Manufacturing Co. and Union Hardware Co., Torrington.

The **Michiel quarry** is in Torrington Township, more than a mile west of Torrington and 340 feet above it. Operators, John de Michiel & Bros., Torrington. Idle in 1922.

The granite (specimen D, XXX, 52) is a muscovite-biotite granite gneiss of medium, inclining to dark bluish-gray color and of medium, very gneissic texture, with feldspar to 0.4 inch and large micas, which are very conspicuous on the foliation faces. Its constituents, in descending order of abundance, are translucent bluish potash feldspar (microcline and orthoclase); light smoky quartz with cavities in sheets and cracks parallel thereto, the sheets of cavities passing uninterruptedly from one particle to the next; a little milk-white soda-lime feldspar (oligoclase), somewhat kaolinized; muscovite (white mica); and biotite (black mica). Accessory: Garnet, apatite, zircon. Secondary: Kaolin. Both feldspars are intergrown with quartz that is more or less circular in cross section. No effervescence with muriatic-acid test.

The quarry, opened in 1901, was in 1908 about 150 feet square and 15 to 30 feet deep.

Rock structure: The gneiss foliation is vertical, with N. 35° E. course. The sheets, 1 to 14 feet thick, are horizontal in the center of the quarry, curving over gently on the sides. There are two sets of joints—(a), strike northwest, dip vertical or steep southwest, spaced about 20 feet; (b), strike N. 20° E., dip steep N. 70° W., spaced 50 feet. The rift corresponds to the foliation, and the grain and hard way are reported as equally pronounced.

The product is used mainly for buildings; some for trimming and curbing. Specimens: Methodist Church, Winsted; Italian Catholic Church, Torrington; L. Ripley residence, Litchfield; trimmings on Litchfield library and on the State armory, Meriden.

The **Torrington Borough quarry** is in Torrington Township, about 1¼ miles north-northwest of Torrington and several hundred feet above it. Owned and operated by the borough of Torrington. Quarry abandoned.

The granite (specimen D, XXX, 51, a) is a biotite granite gneiss of general dark-gray shade, finely banded with black, and very fine to fine schistose texture, with feldspars under 0.1 inch. Its constituents, named in descending order of abundance, are medium-gray potash feldspar (microcline and possibly orthoclase); medium smoky quartz, with cavities in sheets; light-gray soda-lime feldspar (oligoclase), mostly kaolinized and micacized; biotite (black mica); and a little muscovite. Accessory: Pyrite, apatite, zircon. Secondary: Kaolin, a white mica, calcite.

Associated with this gneiss is a mica diorite gneiss (specimen D, XXX, 51, b), a heavy black rock of fine schistose texture. Its constituents, in descending order of abundance, are biotite (black mica); smoky quartz, with cavities in sheets; green hornblende; soda-lime feldspar (andesine), with accessory pyrite (fifth in order of abundance); apatite; and secondary calcite.

Both biotite gneiss and diorite gneiss are crossed by meandering dikelets from under 1 inch to 6 inches thick of a quartz monzonite gneiss (specimen D, XXX, 51 c) of medium bluish-gray color and fine gneissic texture, with feldspar under 0.1 inch and very fine micas. Its constituents, in descending order of abundance, are light smoky quartz with cavities in sheets and cracks parallel thereto; milk-white soda-lime feldspar (oligoclase-andesine), some of it kaolinized, micacized, and with calcite; bluish potash feldspar

(orthoclase), slightly kaolinized; biotite (black mica); and a little muscovite or bleached biotite.

The quarry measured in 1908 about 400 feet from northeast to southwest, with a working face from 30 to 65 feet on the northwest.

Rock structure: The foliation of the main gneisses strikes N. 35°–40° E. and dips 45°–60° W. As stated, they are cut by a network of meandering grayish veinlets of quartz monzonite (specimen c), but they are also crossed by several dikes of pegmatite from 3 to 20 feet thick, the largest and central one of which contains two inclusions of the gneiss measuring 5 by 10 and 2 to 4 by 10 feet. This pegmatite (specimen D, XXX, 51, e) is of medium pinkish-gray color and of very coarse texture, with large feldspars and quartz particles up to 0.5 inch. Its constituents are reddish microcline and orthoclase, but slightly altered; amethystine quartz with cavities in parallel sheets and cracks parallel and at right angles thereto; a little oligoclase, much micacized and kaolinized; muscovite; and biotite. There are crush borders about the feldspars. There are two sets of joints—(a), strike northeast, vertical, forms a heading near the outside of quarry; (b), strike N. 70° W., dip 55° and 30° S. 20° W., spaced 3, 30, and 100 feet. Both sets are slickensided.

The product is used entirely for macadamizing roads in the borough of Torrington. As little as possible of the pegmatite is used, and that is mixed with the gneisses.

WARREN.

The **Comstock prospect** is in Warren Township, a mile north-northeast of Warren village and 2¼ miles east of North Kent. Owner, Reuben Tree Voss, 26 Franklin Street, New York.

The granite (specimen D, XXX, 59, a) is a biotite granite of medium-gray shade and of medium, inclining to fine texture, with feldspars up to 0.2 and 0.3 inch and mica to 0.2 inch. Its constituents, in descending order of abundance, are clear colorless potash feldspar (microcline); pale smoky quartz, with some cavities in sheets; milk-white soda-lime feldspar (oligoclase), a little kaolinized; biotite (black mica); and a little muscovite or bleached biotite. Secondary: Kaolin, limonite. Both feldspars are intergrown with quartz circular in cross section or in vermicular form. No effervescence with muriatic-acid test. The specimen, coming from a long-exposed upper sheet, hardly does justice to the stone.

The opening, made a number of years ago, is 100 feet square and 5 feet deep.

Rock structure: The sheets, 6 to 14 inches thick, are horizontal. There is a 12-inch pegmatite dike on one side. The exposed surfaces are speckled with limonite stain.

Transportation, by cart 3 miles to North Kent, on New York, New Haven & Hartford Railroad.

MIDDLESEX COUNTY.

MIDDLETOWN.

The **Benvenue quarries** are in Middletown Township, about 4½ miles east-southeast of the Middletown railroad station, on the mass south of the bend in Connecticut River and from 200 to 350 feet above it. The nearest railroad stations are Benvenue and Maromas, 1½ miles from the openings. Last operator, Benvenue Granite Co., 41 Park Row, New York. Although these quarries are abandoned they are described on account of their scientific interest.

The granite (specimen D, XXX, 29, a, Maromas granite gneiss, No. 30, of the State preliminary geologic map) is a biotite-hornblende granite gneiss of

dark bluish-gray color and of fine-grained gneissic texture, with porphyritic feldspars up to 0.3 inch and mica up to 0.1 inch. Its constituents, in descending order of abundance, are translucent bluish potash feldspar (microcline and orthoclase); clear colorless quartz, showing effects of strain and with cavities in sheets; milk-white soda-lime feldspar (oligoclase) somewhat kaolinized; biotite (black mica); and hornblende. Accessory: Pyrite, magnetite, titanite, apatite, allanite, zircon. Secondary: Kaolin, epidote. No effervescence with muriatic-acid test.[61]

This is a bright, somewhat foliaceous bluish-gray stone, with strong mineral contrasts.

The Benvenue quarry, about a mile southeast of Benvenue station, half a mile southwest of Maromas, and 200 feet above the river, measures about 400 feet from north to south by 200 feet across and is from 10 to 60 feet deep. The upper quarry, three-fourths of a mile south-southeast of Benvenue station and 350 feet above the river, measures about 300 feet from east to west by 75 feet across, with a working face on the south 40 to over 60 feet high.

Rock structure: At both quarries the gneiss foliation strikes northwest and dips 15° SE. The elongation of the gneiss is in a N. 65° E. direction. The sheets, 6 inches to 6 feet thick, dip 10°–20° E. There are two sets of joints—(a), strike N. 10° E., dip steep, spaced 5 to 20 feet, forms a 10-foot heading on the west side; (b), discontinuous, strike east, dip steep, spaced 5 to 20 feet, forms a 10-foot heading 100 feet from the east end. The rift corresponds to the foliation; the grain is vertical, east–west, and the hardway vertical, north–south. Dikes of white to rose-colored aplite, 1 to 12 inches thick, strike N. 80°–90° W., also N. 35° W. Its particles, less than 1 millimeter, consist of quartz, orthoclase and microcline, oligoclase, and scarce biotite, with accessory pyrite, titanite, and allanite. There are pegmatite dikes of smoky quartz bordered with alternating streaks of oligoclase with microcline and hornblende, up to 3 inches thick, striking N. 75° E. There are also dark-gray elliptical segregations from 2 inches to 3 feet long by 0.5 to 8 inches wide, tapering in the direction of the gneiss foliation. The minerals of these segregations, in descending order of abundance, are microcline with orthoclase, quartz, biotite, oligoclase, hornblende, with accessory apatite, titanite, and zircon.

These quarries were abandoned on account of their overbundance of joints, knots, and dikes.

NEW HAVEN COUNTY.

ANSONIA.

The **Potter quarry** is in Ansonia, about three-fourths mile north-northeast of the center of the village. Operator, William Potter, Ansonia. Idle since 1915.

The granite (specimen D, XXX, 45, a) is a muscovite-biotite granite gneiss of medium bluish-gray color, brightly spangled with mica on the foliation faces, and of fine-grained, unplicated, finely gneissic texture, with feldspars not over 0.2 and mostly under 0.1 inch, but with mica to 0.5 inch. Its constituents, in descending order of abundance, are clear bluish potash feldspar (microline and less orthoclase); clear colorless quartz, with cavities in sheets; translucent bluish soda-lime feldspar (oligoclase), slightly kaolinized; muscovite (white mica); and biotite (black mica). Accessory: Apatite, garnet. Secondary: Kaolin, calcite. Effervesces with muriatic-acid test.

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[61] For a description of the gneiss of this quarry and its structure see Westgate, L. G., A granite gneiss in central Connecticut: Jour. Geology, vol. 7, pp. 638–654, 1899.

The stone glistens brightly with mica on its foliation face, but its other two sides are bluish gray without contrasts. Its foliation adapts it for all uses requiring long flat stones.

The quarry, opened about 1890, measured in 1908 about 200 by 150 feet and 10 to 50 feet deep, with a working face on the northwest 50 feet high.

Rock structure: Foliation and rift strike N. 35° E. and dip 45° S. 55° E. The sheets, 6 inches to 4 feet thick and normal, nearly coincide with the foliation. There are three sets of joints—(a), strike north, vertical, spaced 10 to 30 feet, forms a heading at the west wall, one (20 feet wide) 40 feet from the northeast wall, and another at that wall; (b), strike east-west, vertical, and discontinuous vertically, spaced very irregularly, 3 to 5 feet or more; (c) strike N. 75° E., dip 30° N. 15° W., discontinuous vertically, occurs at rare intervals. There are several pegmatite dikes up to a foot thick. A vertical dike striking N. 15°–22° W. crosses the entire quarry. A group of such dikes, 2 feet wide, has a like course. The pegmatite consists of quartz, feldspar, muscovite, and black tourmaline. Rusty stain is up to 6 inches thick on the lower sheet surfaces.

Transportation, by cart to Ansonia.

The product is used for curbing, crosswalks, steps, and coping, mostly for local demands. The Holbrook quarry in Seymour is on the same belt of rock.

BRANFORD.

The **Norcross quarry** is in Branford Township, about 1¼ miles north of Stony Creek village. (See fig. 87.) Operator, Milford Pink-Victoria White Granite Co., Milford, Mass.

The granite (specimens D, XXIX, 93, a, rubbed; b, c, polished; g, rough; Stony Creek granite gneiss, No. 33 of the State preliminary geologic map), "Branford red granite," is a biotite granite gneiss of medium, reddish-gray color and of very variable but mostly from medium to coarse, not porphyritic, gneissoid texture, with feldspars from 0.1 to 0.3 and even 0.8 inch and mica to 0.2 and 0.3 inch. Its constituents, in descending order of abundance, are reddish potash feldspar (microcline, some intergrown with plagioclase, and less orthoclase), somewhat kaolinized, some micacized, and some bent; medium smoky or smoky amethystine quartz, showing effects of strain and with cavities in streaks and sheets; milk-white or greenish-white to cream-colored soda-lime feldspar (oligoclase to oligoclase-andesine), kaolinized and micacized and with more or less calcite; biotite (black mica), some of it chloritized; and a little muscovite or bleached biotite. Accessory: Magnetite, pyrite, apatite, zircond. Secondary: Kaolin, white micas, calcite, epidote, zoisite, chlorite, limonite. Both feldspars are intergrown with quartz more or less circular in cross section. The stone effervesces with muriatic-acid test.

A specimen of the finer parts (D, XXIX, 93, j) shows feldspar up to 0.1 inch and constituents identical with those given above. A specimen of the extra coarse (pegmatitic) parts (D. XXXIX, 93, e) shows feldspars up to 1 and 1.5 inches. Its constituents are the same as of the others, but the microcline is more dominant and the rock therefore a little more pinkish.

A compression test made at the United States arsenal at Watertown, Mass. (No. 6763), gives this granite an ultimate compressive strength of 22,447 pounds to the square inch, rift and grain directions not recorded. Gillmore gave its specific gravity as 165.4 and its ratio of absorption as 1.201.[62]

[62] Gillmore, Q. A., Report on compressive strength, etc., of various kinds of building stone from different sections of the United States, etc., Engineer Dept., U. S. Army, p. 12, 1874.

The following analysis was made for the firm by Leonard P. Kinnicutt at the Worcester Polytechnic Institute in 1890:

Analysis of biotite granite gneiss from Stony Creek.

Silica (SiO_2)	72.73
Alumina (Al_2O_3) and iron oxide (FeO)	16.95
Lime (CaO)	1.05
Magnesia (MgO)	Trace.
Potash (K_2O)	8.15
Soda (Na_2O)	.90
Loss and undetermined	.22
	100.00

The marked feature of this rock is its very irregular texture, which is due in part to pegmatitic injection, in part to flow structure, and in part probably

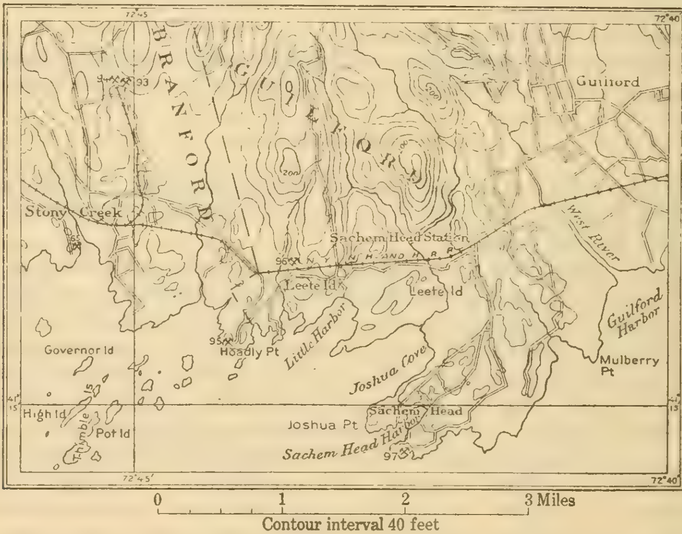

FIGURE 87.—Map of Branford and Guilford, Conn., showing location of granite quarries. 65, Brooklyn; 93, Norcross; 94, Stony Creek; 95, Hoadley Neck; 96, Leete Island; 97, Sachem Head.

to gnessic foliation. These irregularities are shown in the polished slab illustrated in Plate XXX, *A*. In places the rock is a flow gneiss; in others a pegmatite; in others it approaches an aplite in fineness. It is a brilliant stone. Its mineral contrasts lie chiefly between the reddish and whitish feldspars, but these are not everywhere distributed in their normal proportions. It takes a fair polish. The polished face shows some magnetite, some mica, and a little pyrite, and is therefore less suitable for outdoor than indoor use. That its strength and attractive color have more than counterbalanced its irregularity of texture is indicated by the important structures in which it has been used.

The quarry, begun in 1887, consists of a lower opening and an upper one 100 feet north of it. The lower one measured in 1908 about 450 feet north to south by 200 feet across and 15 to 65 feet deep; the upper one, about 500 feet north to south by 100 feet across and 15 to 40 feet deep.

Rock structure: The sheets, 2 to 25 feet thick, are horizontal or inclined 10°–20° SE.[68] There are two sets of joints—(a), strike east, vertical or steep, spaced 5 to 75 feet, in upper quarry confined to the southern 100 feet of the quarry, where their spacing is 5 to 20 feet; (b), strike N. 10° E. and N. 5°–15° W., vertical, forms a 5-foot heading on the east side of the lower quarry and, extending through the upper one, is spaced 10 to 40 feet. The flow structure, consisting of more or less biotitic or nonbiotitic bands, strikes N. 70° W. and dips 35°–55° N. 20° E. to vertical. A slight gneissic foliation is probably also present, but is obscured by the flow structure and the pegmatite. Traces of that foliation appear under the microscope in the strained quartz, bent feldspars, and veinlets of secondary muscovite. The rift is reported as horizontal in the upper quarry and dipping 3°–5° W. in the lower, and the grain as vertical, with N. 20°–30° W. course. A few inches of "shake structure" occur along the sheet surfaces. Both knots and inclusions occur. A microscopic description of a knot, from the neighboring quarry of the Stony Creek Red Granite Co., is given on page 380. Inclusions range from 2 to 1 foot and under to 8 by 3 by 1 foot. One of these (specimen D, XXIX, 93, h) is a black schistose rock with particles under 0.1 inch and consists, in descending order of abundance, of hornblende, andesine, biotite with muscovite, quartz and accessory titanite, magnetite, or ilmenite. It is a quartz-mica diorite gneiss. A medium-gray gneissoid inclusion (specimen D, XXIX, 93, (i), with particles under 0.1 inch, consists, in like order, of oligoclase-andesine, quartz, and biotite, with accessory zircon, and thus is a mica diorite gneiss. Still others (specimens 93, k, kk) are a dark-gray, fine-grained quartz-mica diorite gneiss with oligoclase, quartz, and biotite and accessory pyrite, magnetite, apatite, titanite, and zircon. The coarser feldspars are zonally arranged about some of the inclusions—that is, they have a pegmatitic border. One inclusion is rimmed with biotite.

Transportation, by siding to New York, New Haven & Hartford Railroad, as shown in figure 87.

The product is used mostly for buildings and bridges and some for monuments. Specimens: South Terminal Station, Boston; Bessemer Building, Pittsburgh; Newberry Library and Republic Monument, Chicago; Connecticut River Bridge (arches and coping), Hartford; polished columns (43 feet by 6 feet 2 inches at base) of Battle Monument, West Point; obelisk (45 feet long) at Locks Park, Saulte Ste. Marie, American side (see Pl. XXX, *B*); Lincoln memorial, Hodgenville, Ky.; General Staff College and McMillan fountain, Washington; pedestals of Sheridan monument, New York, and of Hooker monument, statehouse grounds, Boston.

The **Stony Creek quarry** is in Branford Township, about 1¼ miles north of Stony Creek village, less than one-fourth mile west-northwest of the Norcross quarry and on the opposite (east) side of the same ridge. (See fig. 87.) Operator, Stony Creek Red Granite Co., Stony Creek. Idle since 1915.

The granite (specimens D, XXIX, 94, a, e, rough and polished, Stony Creek granite gneiss, No. 33 of the State preliminary geologic map), "Stony Creek red granite," is a biotite granite gneiss of medium to coarse, not porphyritic texture. The stone is identical with that of the Norcross quarry, described above, except that in the average specimen submitted the potash feldspars are more reddish and the soda-lime feldspars are a greenish-gray, instead of whitish or cream-colored, having evidently retained more of their original color. The effect is to diminish the contrast between the feldspars. The sections also show

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[68] A view of the sheet structure here is given in a paper by Prof. J. F. Kemp, Granites of southern Rhode Island and Connecticut [etc.]: Geol. Soc. America Bull., vol. 10, pp. 361–382, 1899.

veinlets of secondary muscovite and calcite in the feldspars and of muscovite in the quartz.

The stone effervesces with muriatic-acid test. R. C. Wells, a chemist of this Survey, finds that it contains 0.25 per cent of lime (CaO), soluble in warm dilute 10 per cent acetic acid, which indicates a content of 0.445 per cent of $CaCO_3$ (calcium carbonate, calcite).

The quarry, opened about 1876, consisted in 1908 of two openings, an eastern one measuring about 200 feet in a north-northwest direction by 35 to 50 feet across, with a working face on the east, and a western opening measuring about 400 feet in a north-northwest direction by 75 feet across and from 10 to 30 feet in depth, with a working face on the west. This western opening is about 300 feet south of the other, but on the east side of a ridge about 80 feet high and 300 feet west of that which separates the eastern opening from the Norcross quarry.

Rock structure: The sheets, 2 to 12 feet thick, dip 15° WSW. There are two sets of joints—(a), strike N. 60°–70° E., dip 50°–70° NNW., spaced 10, 15, 70, and 200 feet; (b), strike N. 30°–35° W., vertical, spaced 5 to 40 feet, forms a heading, 5 to 10 feet wide, on the working face of the western opening. There is a marked flow structure, consisting of biotitic planes or bands striking N. 65° E. and dipping 60°–65° NNW. The rift is reported as horizontal, and the grain as vertical with a course N. 35° W. Some of the pegmatite feldspars measure up to 1.5 inches. Some irregular lenses of chloritic quartz are up to 12 inches across. A dark-gray fine-grained knot consists, in descending order of abundance, of microcline and oligoclase in almost equal amounts, biotite, and a little quartz, together with accessory magnetite, apatite, zircon. Rusty stain is up to 8 inches thick on sheet surfaces.

Transportation, by siding to New York, New Haven & Hartford Railroad.

The product is used mostly for buildings. Specimens: Grand Central Terminal Station, Bellevue Hospital, Kent Hall and Philosophy Building of Columbia University; Lord & Taylor Building, New York; Erie County Savings Bank, Buffalo, N. Y.; Rossia Insurance Building, Hartford; First National Bank, New Haven, Conn.; Guardian Trust & Savings Building, Cleveland, Ohio; Baron von Steuben monument, Washington.

The **Opie quarry** is in Branford Township, on the road from Stony Creek to North Branford, about a mile north of Stony Creek station. Operator, C. J. Opie, Stony Creek. Idle since 1915.

The granite, "light pink," is a biotite granite of medium pinkish-gray color and of medium texture, with feldspars up to 0.4 inch and biotite under 0.1 inch. The gneissoid or pegmatitic character of outcrop not determined.

It consists, in descending order of abundance, of pinkish potash feldspar (microcline and orthoclase); pale smoky quartz; whitish to cream-colored soda-lime feldspar (oligoclase-albite), much kaolinized and micacized; biotite; chlorite; and muscovite. Accessory: Magnetite, pyrite. Secondary: Chlorite, kaolin, a white mica, epidote, calcite. Slight effervescence with muriatic-acid test.

It takes a very fair polish.

This quarry was opened in 1916, but is not now in operation.

The **Brooklyn quarry**, no longer worked, is on the point west of Stony Creek village, in Branford. (See fig. 87.) It was visited by Freeman Ward, then of the faculty of the Sheffield Scientific School, Yale University, who contributes the following observations:

"There are a series of openings, extending 600 or 750 feet about parallel with the shore line, which have not been worked for 20 or 25 years or more.

"The sheets range from the horizontal to a dip of 15°. There are six sets of joints—(a), strike N. 19° W.; (b), strike N. 49° W.; (c), strike N. 64°–69° W.; (d), strike N. 79° W.; all dip 75°–85° N.; (e), strike N. 86° E., dips 50°–55° N.; (f), less conspicuous, strike N. 71° E., dip 50°–55° S. 19° E. Inclusions of a biotite and of a hornblende gneiss measure up to 36 by 12 feet, but some are thin and slablike. Perhaps some of the biotitic streaks are elongated inclusions. All the inclusions, especially the large ones, are likely to be well injected with granite, and some of them have segregations of garnets. Pegmatite does not occur in definite dikes but in irregular streaks which have no distinct boundaries and grade imperceptibly into the surrounding granite. This pegmatite has generally the appearance of the typical Stony Creek granite but may be coarser, the maximum size of its feldspars being 3 inches."

The unpegmatized granite (specimen D, XXX, 65, a, Stony Creek granite gneiss, No. 33, of the State preliminary geologic map, collected by Mr. Ward but examined by the writer) is a biotite granite gneiss of somewhat dark reddish-gray color and of even-grained medium texture, with feldspar to 0.3 inch and mica to 0.05 inch. Its constituents, in descending order of abundance, are pale-reddish potash feldspar (microcline and orthoclase), slightly kaolinized; medium smoky quartz, strained and with cavities in sheets; slightly greenish soda-lime feldspar (oligoclase to oligoclase-andesine), more or less micacized and kaolinized; biotite (black mica), some of it chloritized; and a little muscovite or bleached biotite. Accessory: Garnet (fifth in order of abundance), pyrite, zircon. Secondary: Kaolin, a white mica, calcite, chlorite. The stone effervesces with muriatic-acid test.

The **Hoadly Neck quarries** are in the town of Branford, at the end of Hoadly Point. (See fig. 87.) Operator, estate of John Beattie, Peter and John Beattie, jr., executors, Leete Island.

The granite (specimens D, XXIX, 95, c, d, from West quarry, Stony Creek granite gneiss, No. 33 of the State preliminary geologic map), "Hoadly Neck West quarry granite," is a biotite granite gneiss of general medium, inclining to dark reddish-gray color, and of coarse to very coarse banded, plicated gneissic porphyritic texture, consisting of reddish-gray or whitish lenses and bands alternating with or bordered by thin sheets of black mica and with some thin bands of smoky quartz. The lenses, which are distorted feldspar crystals, commonly twins, measure up to 3 inches in length and 1 inch in width, and the mica bands 0.1 to 0.2 inch. The texture as seen in hand specimens is shown in Plate XXXI, A. The foliation is coarsely plicated, the plications up to 10 inches in width, and these are in places faulted, as shown in figure 19 (p. 94). The constituents of this biotite granite gneiss, in descending order of abundance, are reddish potash feldspar (microcline, somewhat kaolinized, with some orthoclase); medium smoky quartz, with cavities in sheets; whitish soda-lime feldspar (oligoclase), intergrown with quartz more or less circular in cross section or in vermicular form and generally much micasized; biotite (black mica), some chloritized; and a little green hornblende. Accessory: Garnet, pyrite, zircon, apatite. Secondary: A white mica, kaolin, limonite about pyrite, calcite. The stone effervesces slightly with muriatic-acid test.

This stone has marked mineral contrasts and striking textural features, as shown in the plate. It is a coarse constructional granite gneiss of warm gray tint.

The stone of the East quarry (specimens D, XXIX, 95, l, m) lacks the coarsely banded porphyritic texture of the other. Its color is medium reddish gray, and its texture is gneissic, even grained medium, inclining to fine, with

feldspars up to 0.3 inch and mica under 0.1 inch. Its constituents are the same as the others, but a thin section shows the light feldspar as oligoclase-albite.

The quarry, opened in 1867, consists of two openings—the West quarry, in 1908 about 1,500 feet east to west by 800 feet across, with a working face from 30 to 70 feet above sea level, and the East quarry, about 2,000 feet long and curving from west to east by 400 feet across, with working face like the other.

Rock structure: In the West quarry there is a plicated gneissic foliation about horizontal, faulted in places with displacement of a few inches. The sheets of that quarry, 2 to 8 feet thick, are horizontal or dip 10° NE. Those of the East quarry, 6 inches to 2 feet thick, turn from the horizontal to dip 10° E. There are three sets of joints in the West quarry—(a), strike N. 80° W., vertical, forms a heading at east end, one 5 to 8 feet wide through the center, spaced 5 to 150 feet; (b), strike about northeast, vertical, spaced 40 to 200 feet; (c), strike N. 20° W., vertical, spaced 10 feet or more. There are two other sets in the East quarry—(d), strike N. 15° E., dip 77° E., spaced 5 to 10 feet or more; (e), strike N. 60° W., vertical, spaced 5 to 10 feet, forms occasional small headings. The rift is reported as horizontal, and the grain as vertical, with N. 65° E. course at the West quarry and N. 75° E. at the East quarry, but the difference in their fissility appears to be slight. Pegmatite dikes (specimen, 95, a), 1 to 3 feet thick, strike N. 20°–45° E. They consist of the same minerals as the gneiss, but in extra coarse particles. There are dikes or bands of fine biotite granite gneiss up to 4 inches thick. Some of these in the West quarry are parallel to the foliation and have been plicated with it, as shown in figure 19. This rock is of medium pinkish-gray color and of very fine to fine gneissic banded texture, with feldspars up to 0.1 inch, The bands of the coarse gneiss are reddish or light and dark gray or black, from 0.05 to 0.4 inch wide, and result from the distribution of the various minerals in parallel laminae. The constituents of this fine gneiss are identical with those of the coarse rock. Allanite is among its accessories. In the East quarry there are dark bands of mica diorite gneiss (specimen D, XXIX, 95, k) up to 2 feet thick, strike N. 62° E., dip 75° N. 28° W., consisting in descending order of abundance, of biotite, oligoclase-andesine, green hornblende, and quartz. These are either inclusions elongated in the direction of the flow or more probably altered basic dikes.

Transportation, either by siding to New York, New Haven & Hartford Railroad at Leete Island station or by water. There are seven docks near the quarries with 8 feet of water at low tide.

The product is used for massive bridge work, buildings, and monument pedestals. Specimens: Anchorage of Suspension Bridge, Niagara; anchorage of first Brooklyn Bridge; approaches and abutments of Madison Avenue Bridge, Harlem River; piers and abutment of Connecticut River Bridge, Hartford; pedestal of Statue of Liberty, New York Harbor; of Gen. Anderson monument, Fort Sumter, S. C.; of soldiers and sailors' monument, Riverside Drive, New York. A polished slab of the West quarry stone, 6 by 3 feet, exposed for 20 years at a house near the quarries has stood exposure well, notwithstanding the coarseness of its mica.

GUILFORD.

The **Leete Island quarry** is in Guilford Township, about 350 feet north-northeast of Leete Island station on the New York, New Haven & Hartford Railroad. (See fig. 87.) Operator, Estate of John Beattie, Peter and John Beattie, jr., executors, Leete Island.

The granite (specimen D, XXIX, 96, a, Stony Creek granite gneiss, No. 33 of the State preliminary geologic map), Leete Island granite, is a biotite

granite of medium reddish-gray color and of granitic or obscurely gneissic, even-grained medium texture, with feldspars up to 0.25 inch and mica to 0.2 inch. Its constituents, in descending order of abundance, are reddish potash feldspar (microcline and orthoclase, the latter intergrown with soda-lime feldspar), generally fresh; medium smoky quartz with cavities in sheets; cream-colored soda-lime feldspar (oligoclase-albite), micacized, kaolinized, and with calcite; biotite (black mica), some of it chloritized; and a little muscovite or bleached biotite. The microcline is intergrown with quartz more or less circular in cross section. There are crush borders about some of the feldspars, and veinlets of muscovite. Accessory: Magnetite, zircon. Secondary: Kaolin, white micas, calcite, chlorite. It effervesces with muriatic-acid test.

This stone resembles that of the Norcross and Stony Creek quarries (pp. 377, 379), but its texture is finer and more regular. Yet it contains here and there some pegmatitic streaks with feldspar up to 2 inches across. Whatever apparent gneissic texture it has is due mainly to flow structure.

The quarry is on the southwest side of a knoll and measures about 650 feet from southeast to northwest by 50 to 150 feet across, with a working face on the northeast about 60 feet high.

Rock structure: The sheets, 1 to 6 feet thick, are arched, being level in the center of the hill and dipping to 20° W. on its west side and 10° E. on its east side. There is but one set of joints, strike about east, vertical, spaced 5 to 100 feet. There are black knots (specimen 96, b) up to 1 by 4 feet, of very irregular outline, of fine-grained black quartz-mica diorite gneiss, consisting (in usual order) of oligoclase, quartz, and biotite, with much magnetite and accessory apatite, and zircon.

Transportation, by siding to adjoining station.

Product: The quarry has not been worked recently, because of the cheaper transportation by water afforded by the location of the firm's other quarries.

The **Sachem Head quarry** is in Guilford Township, on Sachem Head, on the south side of Great or Sachem Head Harbor. (See fig. 87.) Operator, Coast & Lakes Contracting Corporation, 25 Broad Street, New York. Abandoned in 1914.

The granite (specimens D, XXIX, 97, a, b, c, d, Stony Creek granite gneiss, No. 33 of the State preliminary geologic map), Sachem Head granite, is a biotite granite gneiss of medium, more or less reddish gray color and of variably gneissic texture, ranging from medium, inclining to fine, even grained, with feldspar to 0.3 inch, to porphyritic, with a matrix of the same character containing isolated reddish-buff feldspars up to 0.7 inch, and also with pegmatitic streaks with feldspars up to 1 inch. The mica is mostly under 0.1 inch, and the pegmatitic portions up to 0.2 inch. The constituents of this rock, in descending order of abundance, are reddish-buff potash feldspar (microcline and some orthoclase), but slightly kaolinized; medium smoky quartz with cavities in sheets and some cracks roughly parallel thereto; striated milk-white soda-lime feldspar (oligoclase-albite), more or less micacized and with calcite; biotite (black mica), some of it chloritized; and very little muscovite or bleached biotite. Accessory: Magnetite, apatite, zircon. Secondary: One or two white micas, kaolin, calcite, hematite, chlorite, epidote. Veinlets of muscovite and also of calcite. Both feldspars are intergrown with quartz, more or less circular in cross section. The stone effervesces with muriatic-acid test.

Gillmore gave the specific gravity of this granite as 163.7 and its ratio of absorption as 1.162.[64]

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[64] Gillmore, Q. A., Report on compressive strength, etc., of various kinds of building stone from different sections of the United States, etc., Engineer Dept., U. S. Army, p. 12, 1874.

This is a brilliant granite, with greater variations of shade, color, and texture than those of the granite of the Norcross and Stony Creek quarries. The prevalence of "shake structure" has probably prevented its use in buildings and also facilitated its exploitation for other purposes.

The quarry, opened before 1893, has a working face on the east about 1,000 feet long and from 25 to 50 feet high, averaging about 35 feet, which in the course of excavation had in 1907 receded from 450 to 500 feet.[65]

Rock structure: A flow structure or gneiss foliation strikes N. 70° E. and curves vertically. The sheets, 3 to 8 feet thick, are horizontal. There is also a coarse horizontal shake structure spaced 0.5 to 3 inches and even 6 inches. In places these minor sheets are 6 inches thick over the whole face. There are two sets of joints—(a), strike N. 70° E., vertical, spaced 200 to 500 feet; (b), one only, strike N. 40°–45° E., dip 80°. Rusty stain is a foot wide along the sheet surfaces.

Transportation, by a system of tracks which, starting near the working face, converge at the dock where the barges are moored.

Product: Material for the Point Judith (R. I.) and New Haven breakwaters was supplied from this quarry. The quarry has not been operated since 1913.

SEYMOUR.

The **Holbrook quarry** is in Seymour Township, a mile east of Naugatuck River, near the Ansonia line. Operator, Ansonia Quarry Co., Ansonia. Idle in 1920.

FIGURE 88.—Section of Holbrook quarry, Seymour, Conn. Sheet structure less regular than drawn.

The granite (specimens D, XXX, 46, a, b) is a muscovite-biotite granite gneiss of marked medium bluish-gray color, spangled with mica on the foliation face, and of fine-grained, slightly plicated, finely gneissic texture, with feldspars not over 0.2 inch and mostly under 0.1 inch but with mica to 0.5 inch. Its constituents, in descending order of abundance, are clear bluish potash feldspar (microcline and less orthoclase); clear colorless quartz; translucent bluish soda-lime feldspar (oligoclase), slightly kaolinized; muscovite (white mica), and biotite (black mica). Secondary: Kaolin. No effervescence with muriatic-acid test.

The granite is identical in composition with that of the Potter quarry, in Ansonia (p. 376), which lies three-fourths mile south, but this is more markedly bluish. The stone glistens brightly on its foliation face, but its other two sides afford no contrasts. Its foliation adapts it well for all uses requiring long flat stones.

The quarry, opened about 1877, measured, in 1908, about 300 feet from southwest to northeast by 150 feet across and from 50 to 70 feet in depth.

Rock structure: The gneiss foliation strikes N. 25°–30° E. and dips 47° S. 65° E. The sheets, 2 to 5 feet thick, incompletely developed, dip 25°–30° E. There are three sets of joints—(a), strike N. 75° W., vertical, spaced 2 to 30 feet, forms a heading at the south wall and a heading 10 feet wide 75 feet

[65] See U. S. Geol. Survey Bull. 484, pl. 5, 1911, for a view of the working face of this quarry.

north of it; (b), strike N. 25° E., dip 45°–75° S. 65° E. and vertical, spaced 8 to 10 and 30 feet, forms the west wall, and at south end undulates like sheets; (c), undulating, strike N. 30° E., dip 30° N. 60° W.; one at east side. The rift coincides with gneiss foliation, and the grain with the same strike dips 25° W. On the east the gneiss is in contact with an overlying mass of biotite-quartz feldspar schist. (See fig. 88.) This schist (specimens D, XXX, 46, c, d) is more or less intensely plicated. In thin section it consists, in descending order of abundance, of quartz, biotite, microcline with orthoclase, pyrite, and garnet. It is probably of igneous origin. Pegmatite (of feldspar, smoky quartz, muscovite, and black tourmaline) appears in numerous dikes from 6 inches to 2 feet thick. Of a set striking N. 10°–15° W., there are five spaced 15 to 20 feet. Another set of three striking N. 35° E. is spaced 10 to 18 feet. There is very little stain.

Transportation, by cart 1½ miles to railroad at Ansonia.

The product is used for curbing, circulars, marking and hitching posts, crosswalks, trimmings, and concrete for local demands. Specimens: Trimmings on Fountain Hose Fire Co. Building, Ansonia, and on St. Francis Parochial School, Naugatuck.

NEW LONDON COUNTY.

GROTON.

The **Salter quarry** is in Groton Township, on Thames River, three-fifths mile south-southeast of the Groton ferry landing. Operators, John Salter & Son, Groton.

The granite (specimen D, XXX, 4, a, Westerly granite of Rice and Gregory's Manual of geology of Connecticut), "Groton," is a quartz monzonite of medium, slightly greenish gray color, and of even-grained, fine granitic texture, with feldspars and slender micas up to 0.15 inch but mostly not over 0.1 inch. Its constituents, in descending order of abundance, are light-gray soda-lime feldspar (oligoclase), mostly kaolinized and micacized and with calcite; light smoky quartz with hairlike crystals of rutile; medium, slightly greenish gray potash feldspar (microline, slightly kaolinized, with orthoclase); biotite (black mica) some of it chloritized; and a little muscovite or bleached biotite. Accessory: Magnetite, apatite, allanite. Secondary: A white mica, kaolin, calcite, limonite, chlorite.

An estimate of the mineral percentages by the Rosiwal method, applied to a camera-lucida enlargement (25 diameters) of a thin section, yields these results with a mesh of 0.7 inch and total linear length of 43.4 inches: Soda-lime feldspar (oligoclase), 41.25; quartz, 38,00; potash feldspar (microcline and orthoclase), 16.35; black mica (biotite), 2.80; magnetite, 1.60. The average diameter of the particles calculated from the same measurements is 0.0235 inch.

The stone effervesces with muriatic-acid test. R. C. Wells, a chemist of this Survey, finds that it contains 0.18 per cent of CaO (lime) soluble in warm dilute (10 per cent) acetic acid, which indicates a content of 0.32 per cent of $CaCO_3$ (calcium carbonate, calcite).

This is a monumental granite closely related to the blue granites of Westerly, R. I., but of about half as fine a texture. (See p. 406.) The floral carving reproduced in Plate XXXIII, *B*, shows its adaptation to sculpture. As in quartz monzonites generally, the contrast between its polished and cut face is marked. Minute particles of magnetite and pyrite appear on the polished face.

The quarry, opened about 1835, measured in 1908 about 550 feet in a northeast direction by 50 to 100 feet across and from 20 to 30 feet in depth.

Rock structure: The granite forms an apparent dike, 12 feet thick, dipping about 20° E. between two masses of gray and black diorite gneiss (specimen D, XXX, 4, b, New London granite gneiss, No. 35, of the State preliminary geologic map), with a foliation striking N. 65° W. and dipping 75° N. 25° E., which is injected with pegmatite. This gneiss consists of quartz, oligoclase, microcline, and hornblende, named in the usual order. The granite sheets are short, lenticular, 2 to 12 feet thick, and dip 20° SW. The sheets in the gneiss capping, which is 10 to 20 feet thick, are 6 inches to 5 feet thick and dip 15° S. There are no joints. The rift is reported as dipping about 10° NE., and the grain as vertical, with N. 70° E. course. Niles [66] in 1876 reported evidences of compressive strain at this quarry.

Transportation, by cart to wharf or rail at Groton.

The product is mostly monumental stone and some for trimmings. The gneiss is sold for breakwater use. Specimens: Monument to Col. William Ledyard (killed in battle of Groton Heights, 1781) in Ledyard Cemetery, Groton; monument to first four founders of Stonington at Wequetequock burying ground, Stonington; Edward Newman obelisk, Woodlawn Cemetery, New York; Rev. Byron A. Woods sarcophagus, Forest Hill Cemetery, Philadelphia; Charles Tyler statue, Druid Hill Ridge Cemetery, Baltimore; Kennard Celtic cross, Kensico Cemetery, Valhalla, N. Y., shown in Plate XXXIII, *B*.

The **McIntosh quarry** is in Groton Township, on Broad Street extension, a mile northeast of Groton village, on the E. W. Crouch farm.

The granite (specimen D, XXX, 2, a, Mamacoke gneiss, No. 36 of the State preliminary geologic map) is a biotite granite gneiss of general medium pinkish-gray color and of gneissic banded texture, with pinkish and grayish bands from 0.5 to 0.3 inch wide. Its particles are fine, with feldspars up to 0.2 inch. Its constituents, in descending order of abundance, are light-pink potash feldspar (microcline, somewhat kaolinized), intergrown with quartz more or less circular in cross section; light smoky quartz; milk-white soda-lime feldspar (oligoclase to oligoclase-andesine), mostly much kaolinized and micacized and with calcite; biotite (black mica), much chloritized; and a little muscovite or bleached biotite. Accessory: Magnetite, pyrite, garnets, tourmaline, zircon. Secondary: A white mica, kaolin, chlorite, calcite. A band of quartz and microcline is 1.12 millimeters wide. The stone effervesces with muriatic-acid test.

This is an attractive stone, on account of its delicate color and banded texture.

Rock structure: The gneiss foliation is vertical, with about east to west course. The rift is transverse to the foliation. Both rift and grain fractures are smoother than those along the foliation.

The **Eckerlein quarry** is in the township of Groton, about half a mile east-southeast of Center Groton, near the top of a north-south ridge. Operator, Robert Eckerlein, R. D. 1, Groton. Idle since 1913.

The granite (specimen D, XXX, 13, a, related to Westerly granite), "Center Groton granite," is a quartz monzonite of medium, inclining to dark greenish-gray color and of even-grained, fine granitic texture, with feldspars and slender micas up to 0.1 inch. Its constituents, in descending order of abundance, are greenish-gray soda-lime feldspar (oligoclase), micacized and kaolinized and with calcite; light smoky quartz, with hairlike crystals of rutile and cavities in sheets, with cracks parallel thereto; slightly buff-gray potash feldspar (microcline and orthoclase), some of the microcline kaolinized and micacized in center and also intergrown with quartz more or less circular in cross section; biotite

[66] Niles, W. H., The geological agency of lateral pressure exhibited by certain movements of rocks: Boston Soc. Nat. Hist. Proc., vol. 18, p. 279, 1875–76.

(black mica), mostly chloritized and with needles, probably of rutile; and some muscovite or bleached biotite. Accessory: Magnetite, apatite, allanite, rutile. Secondary: Kaolin, white micas, calcite.

Some of the granite (specimen D, XXX, 13, b) is of medium-gray shade and warm tint, with texture and constituents like those of the other. The potash feldspar is, however, faintly pinkish, and the soda-lime feldspar (oligoclase to oligoclase-andesine) is milk-white. Zircon is accessory. Both rocks effervesce with muriatic-acid test.

An estimate of the mineral percentages made by applying the Rosiwal method to a camera-lucida enlargement (25 diameters) of a thin section yields these results with a mesh of 0.8 inch and a total linear length of 45.7 inches: Soda-lime feldspar (oligoclase), 35.18; quartz, 29.90; potash feldspar (microline and orthoclase), 29.67; black mica (biotite), 4.16; magnetite, 1.09. The average diameter of the particles calculated from the same measurements is 0.0256 inch.

These are fine-grained monumental granites, about half as fine as "Blue Westerly" but of different color. (See p. 406.)

Like other quartz monzonites, these cut and hammer light, the cut or hammered face affording not a little contrast of shade to the polished face, which is darker than the rough face.

The quarry, opened in 1855, measured in 1908 about 150 by 100 feet and 25 to 40 feet in depth.

Rock structure: The darker granite (specimen 13, a), is 10 feet thick and overlies the lighter (specimen 13, b). The sheets, 22 inches to 13 feet thick, dip gently east and south. There are two sets of joints—(a), strike N. 15° W., dip 65° E., spaced 5 to 50 feet; (b), strike N. 80° E., vertical, one only in center. The rift is reported as striking north and dipping steep east, and the grain as east–west, with steep south dip. Both are equally marked. A 4-foot pegmatite dike, with feldspars up to 12 inches and muscovite to 6 inches, strikes N. 10° W. Rusty stain is 2 to 4 inches thick on sheet surfaces.

The **Kopp quarry** is in Groton Township, about half a mile southeast of Center Groton and one-fourth mile S. 30° W. of the Eckerlein quarry. Operators, J. K. Kopp & Sons, New London. Quarry abandoned.

The granite (specimen D, XXX, 12, a, related to Westerly granite) is a quartz monzonite of medium, faintly greenish gray color and of even-grained, fine to very fine granitic texture, with feldspars and mica to 0.05 inch.

This is a monumental granite of finer texture than that of the Eckerlein quarry, more nearly like that of "blue Westerly" (see p. 406), and of shade intermediate between specimens a and b of the Eckerlein quarry.

The quarry was opened in 1890.

The stone is used for monuments and cuts light.

The **McGaughey quarry** is in Groton Township, in the village of Mystic, half a mile northwest of Mystic station. Operator, William R. McGaughey, Mystic. Idle in 1922.

The granite (specimens D, XXX, 20, a, b, related to Westerly granite), "Mystic granite," is a quartz monzonite of medium, inclining to dark, faintly greenish-gray color, and of even-grained, fine granitic texture, with feldspars and mica under 0.2 inch. Its constituents, in descending order of abundance, are translucent grayish soda-lime feldspar (oligoclase-andesine), partly kaolinized and micaized; medium smoky quartz with hairlike crystals of rutile and cavities in sheets; clear colorless to faintly pinkish potash feldspar (microcline and orthoclase), intergrown with quartz more or less circular in cross section; biotite (black mica), some of it chloritized; and a little muscovite or bleached biotite. Accessory: Magnetite, pyrite, apatite, allanite, zircon, purple fluorite.

Secondary: Kaolin, a white mica, calcite, chlorite. It effervesces with muriatic acid test.

This is a monumental granite, almost as fine as "blue Westerly" but with more abundant black mica and thus of darker shade. It cuts light gray and polishes dark gray. The polish is fair but shows pyrite and magnetite. The stone is reported as "very hard."

The quarry, opened before 1827, measured in 1908 about 100 feet from east to west by 35 feet across, with a 50-foot working face (cliff) on the south.

Rock structure: The granite forms an apparent dike, 25 feet thick, underlain by a coarse biotite granite gneiss (specimen D, XXX, 20, d, Mamacoke gneiss, No. 26 of the State preliminary geologic map) and dipping gently south into the base of the cliff and also overlain near its top by a similar gneiss. The sheets, 6 inches to 5 feet thick, but mostly under 13 inches, are about horizontal. The foliation of the gneiss dips steep north or vertical. The only set of joints strikes N. 40° E., dips 65° S. 50° E., forms a 10-foot heading in middle, and is spaced 5 to 30 feet. A vertical "blind seam," striking N. 60° E., proves to be a veinlet of a zeolite. (See p. 75.) A vertical pegmatite dike strikes N. 30° W. There are also dikes of pegmatite and aplite in the gneiss. An inclusion of the gneiss, 4 by 2½ feet, lies in about the center of the granite mass.

Transportation, by cart to New York, New Haven & Hartford Railroad.

The product is used for monuments.

EAST LYME.

The **Malnati quarry** is in East Lyme Township, 2 miles northwest of Niantic station and 160 feet above it. Operators, A. Malnati & Co., 76 Liberty Street, Quincy, Mass.

The granite (specimen D, XXX, 7, a, rough; e, polished and hammered, related to Westerly granite), "golden-pink Niantic," is a quartz monzonite of medium pinkish-gray color and of even-grained, fine granitic texture, with feldspars and mica up to 0.1 inch. Its constituents, in descending order of abundance, are light smoky quartz, with hairlike crystals of rutile and with few cavities; translucent pinkish to milk-white soda-lime feldspar (oligoclase), considerably kaolinized, micacized, and with calcite; clear colorless to translucent white potash feldspar (microcline and a little orthoclase); biotite (black mica), some of it chloritized; and a little muscovite or bleached biotite. Both feldspars are intergrown with quartz more or less circular in cross section. Accessory: Magnetite, apatite. Secondary: Hematite from magnetite, kaolin, a white mica, calcite.

A somewhat darker granite (specimen D, XXX, 7, b), "golden-pink dark," from the same quarry, is of medium, inclining to dark pinkish-gray color and of the same texture and composition as the other, but the quartz is more smoky (section shows cavities in sheets), the oligoclase is more altered and darker, and zircon appears. Both granites effervesce with muriatic-acid test.

An estimate of the mineral percentages by the Rosiwal method, applied to a camera-lucida enlargement (25 diameters) of a thin section, yields these results with a mesh of 1.5 inches and total linear length of 27 inches: Quartz, 35.41; soda-lime feldspar (oligoclase), 32.74; potash feldspar (microcline and orthoclase), 29.48; black mica (biotite), 1.93; magnetite, 0.44. The average diameter of the particles, calculated from the same measurements, is 0.0275 inch.

These granites are reddish monumental granites of about half the grade of fineness of "blue Westerly." Owing to streaks which are said to appear

on large polished faces, the stone is used chiefly for rough and hammered or carved work but is admirably adapted for inscriptions, the light pinkish-gray hammered face contrasting strongly with the reddish-brown polished face (specimen 7, e).

The quarry, opened in 1900, measured in 1908 about 250 feet from east to west by 65 feet across and 75 feet in depth.

Rock structure: The granite occurs in a dikelike mass, 40 feet thick, dipping about 20°, between a lower and an upper mass of gneiss, which has a foliation striking N. 30° E. and dipping 50° S. 60° E. This (Mamacoke granite gneiss, No. 36 of the State preliminary geologic map) is a biotite granite gneiss of medium, slightly pinkish gray color and of medium gneissic texture. Its quartz is light smoky with cavities in sheets; its feldspars are light-pink microcline and orthoclase and milk-white oligoclase. The overlying mass is 20 feet thick and is more altered and weathered, its feldspars having largely passed into crystalline kaolin, making the rock very friable. The granite sheets, 3 to 10 feet thick, are short, irregular lenses. There are two sets of joints—(a), strike N. 5°–10° W., vertical, spaced 3 to 15 feet; (b), strike east, vertical, spaced 3 to 15 feet. The rift is reported as north-south and the grain as east-west, both vertical and of like fissility. Rusty stain is 2 to 4 inches thick on sheet surfaces.

Transportation, by cart over 2 miles to Niantic.

The product is used for monuments, which are finished at Quincy, Mass.

The Carlson quarry is in East Lyme Township, about 2 miles northwest of Niantic station and about 600 feet southwest of the Malnati quarry. Operator, William Sieverts, Niantic, Conn.

The granite, "golden-pink," is a quartz monzonite of medium pinkish-gray color and of even-grained, very fine granitic texture, identical in composition and qualities with that of the Malnati quarry, described above.

The quarry, opened in 1900, measured in 1908 about 125 by 75 feet and 10 to 30 feet in depth.

Rock structure: The granite occurs in a dikelike mass, 40 feet thick, dipping about 30° S. between masses of biotite granite gneiss identical with that at the Malnati quarry. The foliation of the overlying gneiss, which is 20 feet thick, strikes N. 80° W. and dips 25°–30° N. 10° E. The granite sheets, up to 10 feet thick, are short shelly lenses with irregular dip. There are two sets of joints—(a), strike N. 40°–55° E., curving vertically, spaced 5 to 12 feet; (b), strike about north, vertical, forms a heading at east side and one or two at west side.

Transportation, by cart 2 miles to Niantic.

The product is used for monuments.

LYME.

The Joshua Rock quarry is in Lyme Township at Joshua Rock, on the east shore of Connecticut River, 2 miles north of Essex Wharf. It is abandoned.

The granite (specimens D, XXX, 17, a, b, Lyme granite gneiss, No. 34, of the State preliminary geologic map), variegated granite, is an aegirite granite gneiss of general medium, inclining to dark, slightly purplish gray color with fine reddish, pinkish, greenish, and black bands, also cherry-red spots. Its texture is fine gneissic, banded with feldspar and black silicate under 0.2 inch. Its constituents, in descending order of abundance, are clear colorless to dense pinkish potash feldspar (microcline), more or less kaolinized and coarsely intergrown with quartz; light smoky quartz with cavities in sheets and cracks parallel thereto; milk-white soda-lime feldspar (oligoclase-albite) more or less kaolinized; and black aegirite (green in thin section). Acces-

sory: Magnetite (or ilmenite), titanite, yellow colophonite (lime-iron garnet), these three in some abundance, zircon, allanite. Secondary: Hematite and limonite stain, calcite, kaolin. No effervescence with muriatic acid test. The banding is due to the varying abundance or absence of aegirite or the preponderance of quartz or feldspar in parallel planes. The quartz and feldspar are stained cherry-red from hematite, either evenly in bands or else in irregularly disseminated spots.

The quarry is on the west side of a cliff 60 feet high, which is the working face.

Rock structure: The gneiss foliation strikes N. 75°–80° W. and dips 45° N. 10°–15° E. There are passages of biotite and other black silicates (dikes or knots?) 1 to 3 feet thick (specimen D, XXX, 17, c). Vertical joints strike north.

The **Selden Neck quarries** are in Lyme Township, on Selden Neck, on the east shore of Connecticut River, opposite Deep River station. Owner, A. W. Parker Co., 361 Fulton Street, New York. Quarries abandoned.

The granite (specimens D, XXX, 15, a, b, Mamacoke gneiss, No. 36, of the State preliminary geologic map) is a hornblende-biotite granite gneiss of medium, inclining to dark reddish-gray color streaked with black, and of fine gneissic texture, with lenses and laminae of black silicates 0.1 to 0.2 inch apart and with feldspar particles under 0.1 inch. Its constituents, in descending order of abundance, are reddish-gray potash feldspar (orthoclase and less microcline); light smoky quartz, with cavities in sheets; a little reddish-gray soda-lime feldspar (oligoclase); greenish hornblende; and biotite (black mica). Accessory: Apatite, zircon. Secondary: Hematite, limonite, kaolin, calcite. Both feldspars are somewhat kaolinized. The stone effervesces slightly with muriatic-acid test.

This is a fine-grained reddish constructional granite with conspicuous bright black streaks and lenses but without other mineral contrasts.

There are two quarries—a southern one east-southeast of Deep River station, and a northern one east of it. The former measures about 250 by 40 feet, with a working face on the east. The other, about one-fourth mile west-northwest of it, measures about 200 feet from east to west, with a working face on the north 60 feet high.

Rock structure: At the south quarry the gneiss foliation strikes N. 80°–85° E. and dips 20°–25° N. 5°–10° W. The sheets, 1 to 3 feet thick, dip with the foliation. There are four sets of joints—(a), strike N. 70° E., dip 75° S. 20° E., spaced 2 to 5 feet; (b), strike north, vertical, spaced 2 to 5 feet; (c), strike N. 40° E., vertical; (d), strike N. 75°–80° W., dip 30° S. 10°–15° W. At the northern opening the gneiss foliation strikes N. 75° E. and dips 25° N. 15° W. The sheets, 2 to 6 feet thick, dip with the foliation. There are two sets of joints—(a), strike N. 50° E., vertical; (b), N. 10° E., vertical or steep east, forming an 8-foot wide heading at east edge of quarry. Pegmatite dikes, 1 inch to 2 feet thick, dip low northeast. The rift at both quarries is parallel to the long axes of the lenses and at right angles to the gneiss foliation. The grain is parallel to that foliation, and the hard way is transverse to it and to the lenses.

OLD LYME.

The **MacCurdy quarry** is in Old Lyme Township, on Duck River, between Lyme village and the Lyme and Blackhall station. Owner in 1908, Mrs. Evelyn MacCurdy Salisbury, 237 Church Street, New Haven. Although this little quarry has not been worked for many years, it is described on account of the attractiveness of its stone.

The granite (specimens D, XXX, 49, b, c, d, the last being a polished cube with edges 3.5 inches), "MacCurdy granite," is a pegmatite with the composition of a biotite granite. Its general color is medium pinkish to reddish gray spotted with black. Its texture is very coarse porphyritic, with feldspars up to 1.5 inches (exceptionally to 4.5 inches) and mica mostly under 0.5 inch (exceptionally up to 1 inch). Its constituents, in descending order of abundance, are pinkish to reddish potash feldspar (orthoclase and microcline, both minutely intergrown with oligoclase), somewhat micacized; light to medium smoky quartz with cavities in parallel or intersecting sheets; light pinkish to cream-colored and milk-white, rarely clear striated soda-lime feldspar (oligoclase), generally micacized; and biotite (black mica), some of it chloritized. Accessory: Magnetite, pyrite, apatite (considerable), and zircon. Secondary: White micas, calcite, hematite, chlorite.[67]

The stone effervesces with muriatic-acid test. R. C. Wells, a chemist of this Survey, finds that it contains 0.46 per cent of CaO (lime) soluble in warm dilute 10 per cent acetic acid, which indicates a content of 0.82 per cent of $CaCO_3$ (calcium carbonate, calcite), the presence of which is also shown in the section.

W. P. Blake, in in 1880, determined the specific gravity of the reddish feldspar as 2.580 and that of the granite as 2.643, and the weight of a cubic foot of it as 165.2 pounds, or 12.106 cubic feet to 2,000 pounds.

The contrasts between its minerals, the cleavage planes of the large porphyritic feldspars reflecting the light, the iridescence of some of the feldspars, and the attractiveness of its general color make this an unusual rock. The polished face brings out the colors still more strongly. It is well adapted in the rough for monumental use and, when polished, for internal decorations. Between 1871 and 1881 this pegmatite was examined more or less thoroughly by James D. Dana, A. Daubrée, Des Cloiseaux, G. W. Hawes, W. P. Blake, C. U. Shepard, and specimens of it were exhibited at the expositions of Philadelphia, 1876, and Paris, 1878. Newberry [68] referred to it in his Tenth Census report on building stones.

The quarry measures about 50 by 30 feet and from 5 to 10 feet in depth, but some rock was probably quarried above the present surface.

Rock structure: Several dikes of the pegmatite, 15 to 22 feet thick, have penetrated a mass of banded gneiss parallel to its foliation, which strikes N. 50°–60° E. and dips 40°–45° N. 30° E. At one point the pegmatite apparently crosses the foliation of the gneiss horizontally. The gneiss (specimen D, XXX, 49, a, Lyme granite gneiss, No. 34 of the State preliminary geologic map) is a biotitic quartz monzonite gneiss of medium, inclining to dark gray color, with fine bands of various grays, and of fine gneissic texture, with particles under 0.2 inch and bands from 0.1 to 0.3 inch. The constituents of the bands crossed by one thin section are, in the usual order, quartz with cavities in many parallel sheets, with rift cracks parallel thereto, some of them filled with fibrous muscovite, also with a set of sparser and finer cracks at right angles to the first set (the rift coincides with the foliation of the rock), oligoclase, orthoclase, and biotite.

Transportation, by cart about half a mile to New York, New Haven & Hartfort Railroad.

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[67] This granite was first examined microscopically by Des Cloiseaux, who regarded the feldspar intergrown with the microcline as albite. See Am. Jour. Sci., 3d ser., vol. 20, p. 335, 1880.

[68] Tenth Census, vol. 10, p. 321, 1884.

Product: The Channing Memorial Church, with its steeple, at Newport, R. I., was built of this stone in 1881. The trimmings, however, were of light and dark gray granite.

STONINGTON.

The **Masons Island quarry** is in Stonington Township, at the northwest end of Masons Island, on Pine Hill. Operators, E. S. Belden & Sons, Hartford. Quarry abandoned.

The granite (specimen D, XXX, 21, a, Mamacoke gneiss, No. 36, of the State preliminary geologic map) is a quartz monzonite flow gneiss of banded light and dark gray shade. Its texture is even grained, fine, banded, with feldspars under 0.2 inch and mica under 0.1 inch. Its constitutents, in descending order of abundance, are pale smoky quartz, with cavities in sheets; milk-white soda-lime feldspar (oligoclase, probably), some of it micacized; clear colorless potash feldspar (microcline, probably a little orthoclase also); and biotite (black mica). Accessory: Magnetite, garnet, allanite, zircon.

The quarry, opened in 1880, measured in 1908 about 200 feet from east to west, with a working face 30 to 60 feet high on the north.

Rock structure: The rock appears to be a granite with flowage bands caused by the different distribution of the biotite in parallel bands. The banding dips low west. There are lenses of coarse pegmatite (white and pink feldspar and biotite) parallel to the bands. There are also dikes of this pegmatite, some vertical, some dipping southeast or northwest.[69] The sheets, 6 inches to 4 feet thick, are horizontal. One joint only, strike about east-west.

Transportation, by track 450 feet to dock on Mystic Harbor.

The product is used entirely for riprap for breakwater construction.

The **New Anguilla quarry** is in Stonington Township, a mile east of Anguilla Creek, and 1½ miles west-northwest of the station at Westerly, R. I. Operator, Morrison Granite Co. (Inc.), Westerly, R. I. Idle since 1913.

The granite (specimen D, XXX, 19, b), "New Anguilla," is a quartz monzonite of medium, slightly bluish gray color and of even-grained, fine granitic texture, with feldspars under 0.1 inch and mica under 0.05 inch. Its constituents, in descending order of abundance, are light smoky quartz with cavities; milk-white soda-lime feldspar (oligoclase), much kaolinized, micacized, and with calcite; in about equal amount slightly bluish-gray potash feldspar (microcline and orthoclase), intergrown with quartz, more or less circular in cross section; biotite (black mica), some of it chloritized; and a little muscovite or bleached biotite. Accessory: Titanite, apatite, magnetite, pyrite, zircon. Secondary: Kaolin, a white mica, calcite. The stone effervesces with muriatic-acid test.

This is a monumental granite resembling "blue Westerly" (p. 406) in color and texture. Like other quartz monzonites, it cuts and hammers light.

The stone from another opening (specimen D, XXX, 19, c) is of light-buff, inclining to medium-gray color and of even-grained, medium texture, with feldspars up to 0.25 inch and mica under 0.1 inch. It consists of cream-colored feldspar, medium smoky quartz, and black mica. It effervesces with muriatic-acid test. This is hardly suitable for monumental use.

The quarry, opened in 1908, measured about 100 feet from east to west by 30 feet across and averaged 4 feet in depth. Another opening 500 feet south was 40 by 20 feet and 5 to 8 feet deep.

Rock structure: The bluish-gray quartz monzonite has a capping of gneiss 3 to 5 feet thick. This (specimen D, XXX, 19, a), probably Putnam gneiss of

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[69] J. F. Kemp described this pegmatite in his Granites of southern Rhode Island and Connecticut: Geol. Soc. America Bull., vol. 10, pp. 373, 374, 1899.

Rice and Gregory,[70] is a biotite granite gneiss of medium gray shade, finely banded with dark gray, and of fine to very fine unplicated gneissic texture, with feldspars under 0.1 inch and mica under 0.05 inch. Its constituents, in the usual order, are microcline, quartz, oligoclase, and biotite, with accessory magnetite, apatite, zircon, allanite. The foliation strikes nearly east and is vertical. The contact between granite and gneiss is in places very jagged or bordered with 12 inches of pegmatite and aplite, which also penetrate the gneiss. The sheets, exposed in 1908, were 6 inches to 5 feet thick. There are three sets of joints—(*a*), strike east, vertical; (*b*), strike north, vertical and discontinuous; (*c*) (one only), strike N. 60° W., dip 55° S. 30° W. The rift is reported as horizontal, and the grain and hard way as equally fissile. The flow structure dips 25° S. At the south opening a dike or band of the quartz monzinite, 10 feet wide, has the medium-grained granite, described on page 392, on both sides of it. Flow structure dips 50°–70° S.

Transportation, by cart 2 miles to Westerly, R. I.

The blue-gray quartz monzonite is used for monuments.

The **Murray quarry** is in the village of Pawcatuck, in Stonington Township, about three-fourths mile northwest of Westerly station. Quarry no longer operated.

The granite (specimen D, XXX, 18, a, Sterling granite, No. 24 of the State preliminary geologic map), "red Westerly," is a biotite granite of dark, inclining to medium reddish-gray color and of even-grained granitic medium, inclining to coarse texture, with feldspar up to 0.4 inch (exceptionally 0.5 inch) and mica to 0.2 inch, but mostly under 0.1 inch. Its constituents, in descending order of abundance, are reddish potash feldspar (microcline and orthoclase), slightly kaolinized; amethystine smoky quartz, with cavities in sheets; cream-colored striated soda-lime feldspar (oligoclase to oligoclase-albite), much kaolinized and micacized, in places stained red from hematite; biotite (black mica), some of it chloritized; and a little muscovite or bleached biotite. Accessory: Magnetite, pyrite, apatite, allanite, zircon. Secondary: White micas, kaolin, chlorite, calcite, limonite from allanite, hematite from magnetite. Marked effervescence with muriatic-acid test.

This is a brilliant constructional granite of attractive tint. Its mineral contrasts are between its black mica and pink and cream-colored feldspar. The stone is identical with that of the Redstone quarry at Westerly, R. I. (See p. 412.)

Another biotite granite (specimen D, XXX, 18, b) from the same quarry is of dark, inclining to medium, slightly reddish-gray color. It is a little darker and less reddish than the stone described above. Its texture is even-grained medium, with feldspar to 0.3 inch and mica to 0.1 inch. Its constituents are like those of the other, but the soda-lime feldspar is of greenish-gray color. The effect of this and of the finer texture of the stone is to darken its general shade.

The quarries, opened about 1889, are two—a northern one, measuring in 1908 about 150 by 75 feet, with a 40-foot working face on the west, and a southern one, separated from the other by a 50-foot mass and consisting of two 50-foot square openings, one east of the other.

Rock structure: The sheets, 2 to 10 feet thick, dip gently north and, at the south end, west. There are three sets of joints—(a), strike N. 60° E., dip 65°, spaced 4 to 20 feet and over; (b), strike N. 82° E., vertical, reddish, coated with epidote, spaced 2 to 20 feet; (c), strike N. 25° E. Flow structure

[70] Manual of the geology of Connecticut: Connecticut Geol. and Nat. Hist. Survey Bull. 6, p. 132, 1906.

and grain strike east; the former dips 60°. The rift is reported as horizontal. Pegmatite dikes (specimen D, XXX, 18, c) up to 6 inches thick strike N. 60° W. The unquarried mass between the two quarries and about 10 feet of the south end of the northern quarry consist of the finer darker granite (specimen b), which constitutes a dike or band.

Transportation, by cart 1 mile to railroad at Westerly, R. I.

The product of the main quarry (specimen a) was used for building and trimming; that of the smaller (b) for monuments.

WATERFORD.

The **Scott quarry** is in Waterford Township, 3 miles north of New London, on Bolles Hill, about half a mile south of Quaker Hill village. Quarry abandoned.

The granite (specimen D, XXX, 9, b), Mamacoke gneiss, No. 36 of the State preliminary geologic map) is an aegirite granite gneiss of medium pinkish to purplish gray color and of very fine, slightly gneissic, in places banded texture, with feldspar under 0.1 inch (rarely to 0.15 inch) and black silicate under 0.05 inch. Its constituents, named in descending order of abundance, are grayish to pinkish potash feldspar (microcline and orthoclase), intergrown with soda-lime feldspar (oligoclase-albite) and somewhat kaolinized; light smoky quartz with cavities in sheets; a little separate soda-lime feldspar of the same kind; black aegirite (green in thin section). Accessory: Magnetite, titanite. Secondary: Kaolin, hematite stain. No effervescence with muriatic-acid test.

A specimen (D, XXX, 9, a) of a part with alternating black, gray, and reddish plicated bands from 0.1 to 0.3 inch wide shows the same minerals with zircon, but the soda-lime feldspar is albite or oligoclase-albite and all separate. Some of the bands are largely quartz, others largely feldspar, still others mainly aegirite.

The quarry, opened in 1898, measured in 1908 150 feet along the highway by 50 feet from it and averaged 5 feet in depth, with a working face 20 feet high at the back.

Rock structure: The sheets, 1 to 4 feet thick, are about horizontal. Two sets of joints occur at rare intervals—(a), strike N. 10° W., dip 60° W.; (b), strike N. 65° E., vertical. The gneiss foliation strikes N. 10° W. and N. 20° E. and dips east. At one point this is sharply plicated along the strike. The rift is reported as vertical east to west and the grain as vertical north to south. Dikes or lenses of pegmatite and aplite up to 2 feet thick run with the foliation.

The product is underpinning, curbing, trimmings, steps, and paving. The quarry is worked only occasionally.

The **Millstone quarry** is in Waterford Township, on Millstone Point, 5 miles southwest of New London. (See fig. 89.) Operator, Henry Gardiner, Millstone.

The granite (specimens D, XXX, 6, a, b, k, polished, d, e, rough, related to Westerly granite of Rice and Gregory), "Millstone granite," is a quartz monzonite between medium and dark gray, smoky, and of even-grained granitic, fine texture, with feldspars up to 0.2 inch but mostly under 0.1 inch and mica to 0.1 inch. Its constituents, named in descending order of abundance, are whitish to buff striated soda-lime feldspar (oligoclase-albite), much of it kaolinized and micacized and intergrown with quartz circular in cross section; translucent gray potash feldspar (microcline and a little orthoclase), little altered; medium smoky quartz, with some cavities in sheets; biotite (black

mica), some of it chloritized; and very little muscovite or bleached biotite. Accessory: Magnetite (fifth in abundance), allanite (sixth in abundance), pyrite, apatite, zircon. Secondary: Kaolin, a white mica, limonite from allanite, calcite, chlorite.

An estimate of the mineral percentages by the Rosiwal method, applied to a camera-lucida enlargement (25 diameters) of a thin section, yields these results with a mesh of 1.7 inches and total linear length of 40.8 inches: Soda-lime feldspar (oligoclase-albite), 34.22; potash feldspar (microcline and orthoclase), 31.81; quartz, 25.54; black mica (biotite), 7.21; magnetite, 0.93;

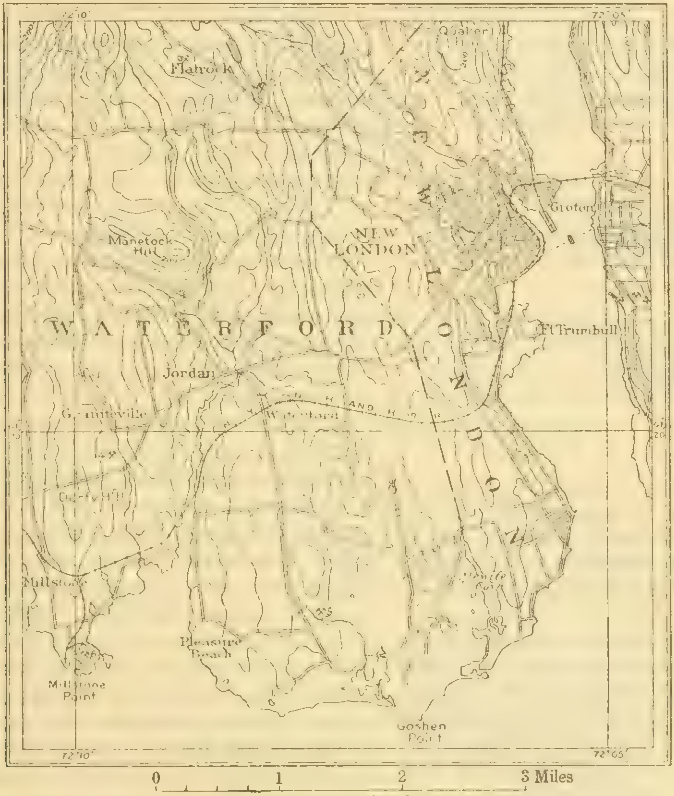


FIGURE 89.—Map of southern part of Waterford, Conn., showing location of granite quarries. 1, Flat Rock; 3, Goos; 5, Waterford; 6, Millstone; 14, Somers.

allanite, 0.29. The average diameter of the particles calculated from the same measurements is 0.0354 inch.

This granite effervesces somewhat freely with cold dilute muriatic acid. R. C. Wells, a chemist of this Survey, finds that it contains 0.31 per cent of CaO (lime), soluble in warm dilute (10 per cent) acetic acid, which indicates a content of 0.55 per cent of $CaCO_3$ (calcium carbonate, calcite). Calcite is also shown by the microscope.

A transverse test (No. 9764) made at the United States arsenal at Watertown, Mass., in 1896, on a piece of this granite 18 inches long by 1.02 by 1.02 inches and with 15 inches between end supports, gave a modulus of rupture of 2,029 pounds, the piece breaking under 138 pounds.

This is a brilliant, somewhat fine-grained smoky monumental and inscriptional granite without mineral contrasts except on close inspection. Its texture is about one-third as fine as that of the coarser "blue Westerly" granite (New England Granite Works quarry, 0.0112 inch).

It takes a high polish, but the polished face shows magnetite and some pyrite. It hammers and cuts medium gray, thus affording a marked contrast of shade to the polished face, which is dark gray.[71]

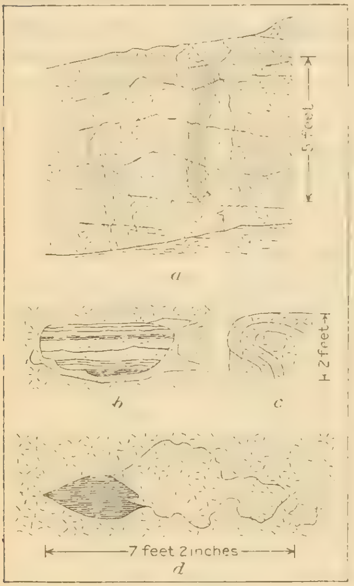


FIGURE 90. — Details at Millstone quarry, Waterford, Conn. *a*, Vertical section of pegmatite dike in quartz monzonite, with inclusions of biotite gneiss (after a photograph by E. F. Burchard, U. S. Geol. Survey); *b*, horizontal section of inclusion of biotite gneiss, 20 by 8.5 inches, partly surrounded with pegmatite, in quartz monzonite; *c*, vertical section of tortuous flow structure, consisting of biotite sheets; *d*, horizontal section of inclusion of gneiss associated with very coarse pegmatite in quartz monzonite.

A pinkish variety (specimen D, XXX, 6, i), "Millstone pink," no longer quarried, is a quartz monzonite of medium, inclining to dark, slightly pinkish gray color, with unevenly distributed cherry-red stains. Its texture is a trifle coarser, the feldspars and mica mostly under 0.15 inch. Its composition is identical with that of the other but includes secondary hematite, which causes the cherry-red spots.

The quarry, opened in 1830, measured in 1908 about 800 feet in a N. 40° W. direction and had a width varying from about 150 to 300 feet, owing to two embayments on the northeast wall, and a depth of 50 to 150 feet.[71a]

Rock structure: The relations of granite and gneiss here have been described on page 89. The gneiss (specimen D, XXX, 6, f, Mamacoke gneiss, No. 36 of the State preliminary geologic map) appears to be a black and white banded biotite granite gneiss of fine to medium texture. The granite sheets, lenticular, normal, and mostly 2 to 8 feet thick, but 6 to 12 inches in the upper 20 feet of the southeast end and 6 inches to 2 feet in the upper 15 feet of the central northeast side, dip 20° N. 65° E. There are two sets of joints—(a), strike N. 40° W., vertical, forming parts of the northeast and southwest walls and a 30-foot heading at the north-northwest corner, spaced 6 inches to 33 feet but mostly 3 to 10 feet; (b), strike north to N. 10° E., steep, occurs at greater and irregular intervals. A little sea water enters the quarry at the bottom through some of these joints. Flow structure, indicated by biotitic bands, strikes N. 45°–60° W. and dips 30° SW., but near the northwest end of the quarry the bands are tortuous, doubling over on themselves, as shown in figure 90, *c*. A block in the storage yard with a concentric structure of this kind probably formed part of a turn in one of these granite

[71] J. S. Newberry in 1884 described it as "a dark-gray granite of fine, homogeneous texture, showing strong contrast of color between polished and dressed surfaces." Tenth Census U. S., vol. 10, p. 321, 1884.

[71a] See Kemp, J. F., op. cit., pl. 36, fig. 2, for a view of the quarry as it appeared between 1888 and 1898.

currents. The rift is reported as dipping 5°–10° N. 80° E., and the grain as vertical, with N. 65° E. course. Pegmatite and aplite dikes dip 30° at intervals of 3 to 10 feet. One with large biotite crystals strikes N. 55° E. There are many inclusions. Some have been described on page 62 and are shown in figure 90. Rusty stain is about 2 inches thick on sheet surfaces. Niles,[72] in 1876, mentioned the crushing of channel cores and cramping of drills at this quarry by northeast-southwest compression.

Transportation, by siding 1 mile to New York, New Haven & Hartford Railroad at Millstone station and also by short siding to dock, which admits vessels of 12-foot draft at low tide.

The product is used for monuments and buildings, and the waste for breakwater riprap, road, and concrete material. Specimens: Saratoga Monument, interior, entrance, and all but upper 10 feet of exterior; also a polished inscribed tablet of the Millstone pink; base, pedestal, and cap of Barnum monument, Bridgeport; George W. Childs mausoleum, Philadelphia.

The **Somers prospect** is in Waterford Township, 2½ miles west-southwest of New London, on the east side of Durfy Hill, near Graniteville. (See fig. 89.) This is a small opening, made in 1902.

The granite (specimen D, XXX, 14, b, related to Westerly granite of Rice and Gregory) is a quartz monzonite of medium, inclining to dark buff-gray color and of even-grained granitic fine texture, with feldspar mostly under 0.1 inch but up to 0.2 inch and mica mostly under 0.05 inch but up to 0.1 inch. This rock is overlain by a few feet of similar but pinkish granite (specimen D, XXX, 14, a). Both effervesce slightly with muriatic-acid test.

This granite is finer textured than that of the Millstone quarry, and specimen 14, b, is a little lighter in color. Specimens taken from upper 8 feet.

Rock structure: The sheets are irregular, 1 to 8 feet thick, dipping 30° E. Joints (a), strike nearly east, vertical, spaced 9 to 20 feet; (b), strike north, dip west, discontinuous, one only. There is some pegmatite.

The **Waterford quarry** is in Waterford Township, 3½ miles south-southwest of New London, 2¾ miles south of Waterford station, and a mile east of Pleasure Beach. (See fig. 89.) Operator, Booth Bros. & Hurricane Isle Granite Co., 208 Broadway, New York.

The granite (specimens D, XXX, 5, a, b, rough, d, polished and hammered, related to Westerly granite of Rice and Gregory), "Connecticut white," is a quartz monzonite of medium buff-gray color and of even-grained granitic, fine texture, with feldspar up to 0.2 inch, rarely 0.3 inch, but mostly under 0.1 inch, and slender micas up to 0.15 inch, rarely 0.2 inch, but mostly not over 0.1 inch. The long axes of the micas are parallel to the rift. Its constituents, in descending order of abundance, are milk-white soda-lime feldspar (oligoclase-andesine), kaolinized and micacized; cream-colored potash feldspar (microcline and a little orthoclase), slightly kaolinized and intergrown with quartz more or less circular in cross section; light smoky quartz, with hairlike crystals of rutile, rare cavities in sheets, and some rift cracks parallel thereto; biotite (black mica), some of it chloritized; and very little muscovite or bleached biotite. Accessory: Magnetite (fifth in order of abundance), apatite, zircon, allanite; no pyrite detected. Secondary: A white mica, kaolin, calcite, chlorite, limonite.

An estimate of the mineral percentages by the Rosiwal method applied to a camera-lucida enlargement (25 diameters) of a thin section yields these results with a mesh of 1 inch and a total linear length of 27 inches: Soda-lime feldspar (oligoclase-andesine), 33.63; potash feldspar (microcline and little orthoclase),

[72] Niles, W. H., The geological agency of lateral pressure exhibited by certain movements of rocks: Boston Soc. Nat. Hist. Proc., vol. 18, for 1875–76, p. 279.

32.29; quartz, 29.92; black mica (biotite), 3.65; magnetite, 0.51. The average diameter of the particles, calculated from the same measurements, is 0.0206 inch.

The stone effervesces with muriatic-acid test. R. C. Wells, a chemist of this Survey, finds that it contains 0.29 per cent of CaO (lime), soluble in warm dilute (10 per cent) acetic acid, which indicates a content of 0.51 per cent of $CaCO_3$ (calcium carbonate, calcite); calcite is also shown by the microscope.

The following analysis (No. 12757) of this granite, made for the company by Ricketts & Banks, of New York, is given here for reference:

Analysis of quartz monzonite from Waterford quarry.

Silica (SiO_2)	68.11
Alumina (Al_2O_3)	14.28
Iron oxide (FeO)	2.63
Lime (CaO)	1.86
Magnesia (MgO)	.68
Potash (K_2O)	5.46
Soda (Na_2O)	6.57
Sulphur (S)	.34
	99.93

Ira H. Woolson, E. M., of Columbia University, made two compression tests on cubes of 2-inch edges in 1896, with these results (rift and grain directions not noted):

Test No.	First crack.	Maximum stress.	Ultimate strength.
	Pounds.	*Pounds.*	*Pounds per sq. in.*
1575	65,000	93,100	23,510
1576	92,000	97,600	23,921

This is a very fine-graded monumental and inscriptional granite of buff to medium-gray tint without mineral contrasts. It is finer and lighter than the "Millstone granite" and about half as fine as "blue Westerly" which averages 0.0099 inch per particle. (See p. 406.)

It takes a high polish. The polished face shows a little magnetite and is of medium inclining to dark gray shade; the hammered face is a light gray, to which the stone owes its trade name. This property of hammering and cutting light it possesses in common with "Westerly," "Groton," "Millstone," and other quartz monzonites. Its adaptation, to fine architectural and sculptural work is shown in Plates XXXII and XXXIII, *A*, and its lightness when hammered in Plate XXXII.

The quarry, opened about 1878, measured in 1908 about 600 feet from east to west by 150 feet across at the east end and 250 feet at the west end and from 75 to 125 feet in depth.

Rock structure: The granite occurs in two dikelike masses, 30 and 40 feet thick, as described in detail on page 89, and shown in figures 13 and 14. There are three sets of joints—(A), vertical, spaced 3 to 20 feet; (B), vertical or steep west, spaced 3 to 50 feet; (C), dip 50°–75° NW., spaced 2 to 75 feet. (See fig. 91.) The rift dips 10° S. 15° E., with the long axes of the biotite scales, the grain dips 75° N. 15° W., and the hard way is vertical. Joint, rift, and grain courses are shown in figure 91. In splitting along the rift the granite is reported as breaking more readily from the west side than from the north. Biotitic knots up to 6 inches in diameter are rare. Inclusions of the gneiss, 3

inches across and 2 by 3 feet, occur 2½ and 6 feet above the contact of the upper granite dike underlying gneiss. The granite surface tends to weather spheroidally. (See p. 72 and Pl. XXIX, *B*.) Rusty stain is 2 to 6 inches thick on sheet surfaces.

Transportation, by cart 1 mile to dock at Pleasure Beach, which admits vessels of 9 feet draft at low tide, or 2 miles to New York, New Haven & Hartford Railroad at Waterford station.

The product is used mostly for monuments.

Specimens: Soldiers' monument, Whitinsville, Mass., shown in Plates XXXII and XXXIII, *A*; Chelsea Savings Bank, Norwich, Conn.; Littlefield shaft, Swan Point Cemetery, Providence, R. I.; Hoy mausoleum, Mount Moriah Cemetery, Philadelphia; City Deposit Bank, Pittsburgh, Pa.; Clark residence (basement), Riverside Drive, and Dudley Celtic cross, Woodlawn Cemetery, New York; soldiers and sailors' memorial (Cyrus E. Dallin, sculptor), Syracuse, N. Y.; Alexander Hamilton memorial (Bela Pratt, sculptor), Grant Park, Chicago.

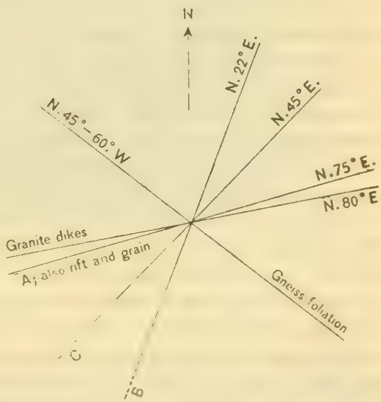


FIGURE 91. — Structure at Waterford quarry, Waterford, Conn.

TOLLAND COUNTY.

BOLTON.

The **Petersen quarry** is in Bolton Township, in the northeastern part of Minnehausch or Birch Mountain, about 2 miles southwest of Bolton village and 1¾ miles southeast of Highland Park post office, in Manchester. The quarry is not in operation.

The granite (specimens D, XXX, 31, **a, b, Glastonbury granite gneiss, No. 15** of the State preliminary geologic map) is a biotite granite gneiss of medium, slightly bluish-gray color, with conspicuous broad black streaks on the foliation face, and of medium-grained unplicated, very gneissic texture, with porphyritic lenticular feldspar up to 0.2 and 0.4 inch long. The quartz is in lamellae up to 0.1 inch thick and the mica to 0.04 inch. The stone looks very different on its rift, grain, and hard-way sides. Its constituents, in descending order of abundance, are translucent bluish potash feldspar (microcline and orthoclase), somewhat kaolinized; light smoky quartz, strained and with cavities in parallel sheets and cracks parallel to or coinciding therewith; milk-white soda-lime feldspar (oligoclase to oligoclase-andesine); and biotite (black mica). Accessory: Garnet, pyrite. Secondary: A white mica, kaolin. Both feldspars are intergrown with quartz more or less circular in cross section. The stone does not effervesce with muriatic-acid test.

The quarry is a small opening, made in 1908.

Rock structure: The sheets, 3 feet thick, dip gently east. The gneiss foliation strikes N. 10° E. and is vertical. The rift is parallel to it, the grain horizontal, and the hard way vertical, east-west. An 18-inch aplite dike runs parallel to the foliation. This (specimen D, XXX, 31, c) is of medium bluish-gray color and of fine, slightly gneissic texture. Its constituents, in the usual order, are smoky quartz; bluish microcline, with orthoclase; milk-white soda-lime feldspar; and a little sparse biotite and pyrite. Its quartz and feldspar particles are mostly from 0.11 to 0.33 millimeter, with some porphyritic ones 0.54 to 0.84 millimeter.

The contrasts in this stone are more marked than in any of the gneisses of Glastonbury described on pages 366–369.

The stone was used for underpinning and cellar stone and is well adapted to sills.

WINDHAM COUNTY.

STERLING.

The **Oneco quarry** is in Sterling Township, 1 mile southwest of Oneco village, near the Rhode Island line. (See Pl. XXVIII.) It is now disused.

The granite (specimen D, XXX, 22, a, Sterling granite gneiss, No. 24 of the State preliminary geologic map) is a biotite granite gneiss of medium, inclining to dark, slightly bluish-gray color and of fine-grained unplicated gneissic texture, with porphyritic feldspars up to 0.2 and 0.4 inch and mica in fine parallel streaks 0.1 to 0.2 inch apart. Its constituents, in descending order of abundance, are bluish potash feldspar (microcline intergrown with quartz more or less circular in cross section, also orthoclase), somewhat kaolinized; light smoky quartz, with cavities in parallel sheets and cracks parallel thereto; a little milk-white soda-lime feldspar (oligoclase), some of it kaolinized and micacized; and biotite (black mica). Accessory: Titanite (fifth in order of abundance), magnetite (or ilmenite), garnet, apatite, allanite, zircon. Secondary: Kaolin, white mica. No effervescence with muriatic-acid test.

The quarry, opened about 1868, measured in 1908 about 500 feet from northwest to southeast by 400 feet across and 35 feet in depth.

Rock structure: The gneiss foliation strikes N. 10°–25° W. and is vertical. The sheets, up to 5 feet thick, dip 5°–10° SW. and NW. Joints (*a*), strike N. 80°–85° E., vertical, spaced 10 feet and much more; (*b*), "blind seams" with quartz and pegmatite dikelets, strike N. 30° W., dip 50° E., spaced 3 to 10 feet. Biotitic surfaces (flow structure?) strike N. 30° W., and dip 50° N. 60° E. The rift is reported as parallel to the gneiss foliation, and the grain is vertical, east to west, feeble. There are pegmatite lenses of smoky quartz and pink feldspar, with purple fluorite and epidote crystals. Dikes of whitish aplite up to 4 inches thick strike N. 50° W. (See microscopic description under Marriott quarry, below.)

Transportation, by siding to Central New England Railway.

The product was used for building, curbing, and paving, and the waste for crushed stone.

The **Marriott quarry** is in Sterling Township, 1 mile southwest of Oneco station and one-fourth mile east of the Oneco quarry. Operators, R. B. Marriott & Sons, Oneco.

The granite (specimens D, XXX, 23, a, b, Sterling granite gneiss, No. 24 of the State preliminary geologic map), "Oneco," is a biotite granite gneiss of medium, inclining to dark bluish-gray color and of fine-grained unplicated gneissic texture, with porphyritic feldspar up to 0.2 and 0.4 inch and mica in fine parallel streaks 0.1 to 0.2 inch apart. Its constituents are identical with those of the Oneco quarry stone, but the section shows secondary calcite, and the stone effervesces slightly with muriatic-acid test.

This granite gneiss is well adapted by its foliation for curbing and trimmings. It has a marked bluish tint and looks well hammered on the grain and hard-way sides.

The quarry, first opened in 1881, reopened in 1903, measured in 1908 about 200 by 150 feet and 15 feet in depth.

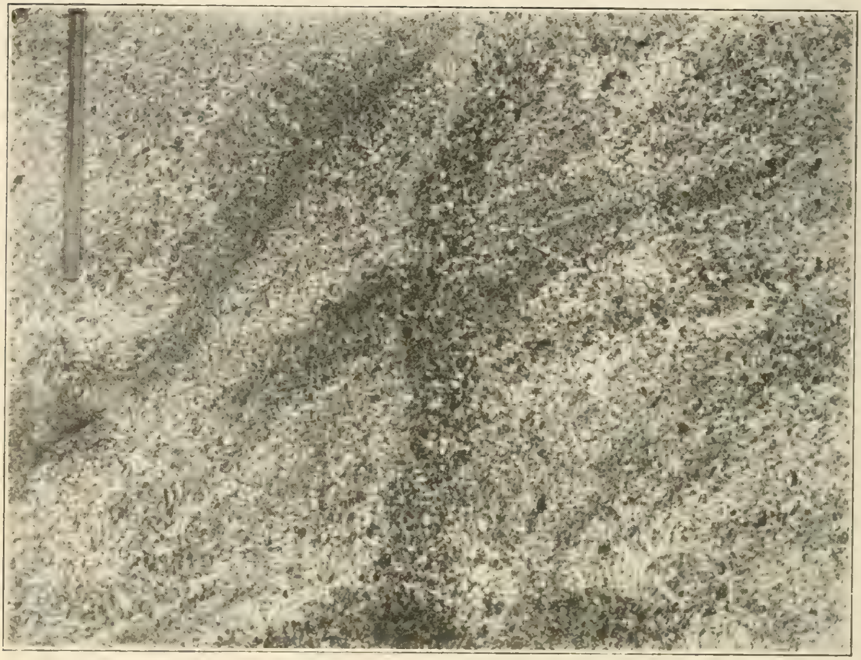
Rock structure: The gneiss foliation strikes north to N. 15° W. and is vertical. The sheets, 1 to 7 feet thick, dip 5° E. There are two sets of joints—(*a*), strike

A. GRANITE GNEISS FROM LEETE ISLAND QUARRY, CONN.

Showing gneissoid texture due to squeezing and stretching of granite. Photograph by H. E. Gregory.

B. OVOIDAL BLOCK OF VERY FINE QUARTZ MONZONITE PRODUCED BY WEATHERING WITHIN A HEADING AT REDSTONE QUARRY, WESTERLY, R. I.

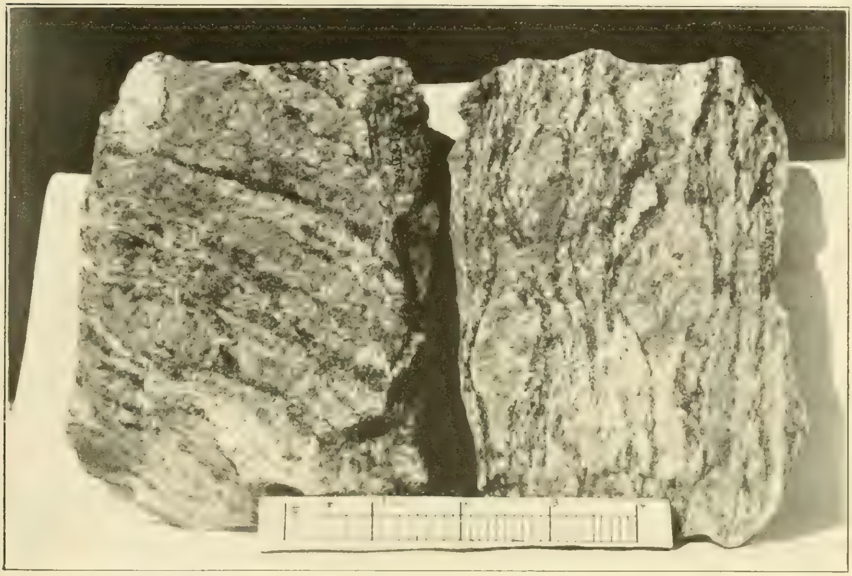
Hammer 20½ inches long.



A. POLISHED SLAB OF PEGMATITIC BIOTITE GRANITE GNEISS, "BRANFORD RED," FROM NORCROSS QUARRY, STONY CREEK, CONN.

Showing irregularity in size of grains owing to pegmatitization and in their arrangement owing to flow structure, and probably also in part to gneissic foliation. Rule 12 inches long.

B. OBELISK OF HAMMERED PEGMATITIC BIOTITE GRANITE GNEISS, "BRANFORD RED," FROM THE NORCROSS QUARRY, STONY CREEK, CONN



A. COARSE PORPHYRITIC BIOTITE GRANITE GNEISS FROM HOADLY POINT "WEST" QUARRY, BRANFORD, CONN.

Showing the lenticular shape of the feldspars owing to elongation and the distribution of the mica and quartz in bands.

B. PORPHYRITIC GRANITE GNEISS FROM DERBY, CONN.

Showing the isolated feldspar crystals (phenocrysts). Photograph by H. E. Gregory

SOLDIERS AND SAILORS' MONUMENT AT WHITINSVILLE, MASS.

Made of hammered buff-gray fine quartz monzonite from Booth quarry at Waterford, Conn. A. D. F. Hamlin, architect. H. A. MacNeil, sculptor. Height to top of ball, 30 feet. Eagle of bronze.

A. PANEL WITH BAS-RELIEF AT BASE OF MONUMENT SHOWN IN PLATE XXXII.

Height of relief, 0.5 inch.

B. CARVED MONUMENT OF GREENISH-GRAY FINE QUARTZ MONZONITE FROM THE SALTER QUARRY AT GROTON, CONN.

Height of relief, 2½ inches; height of cross, 12 feet.

A. CONTACT OF GRANITE (QUARTZ MONZONITE) WITH OVERLYING GRANITE GNEISS ON WEST SIDE OF KLONDIKE QUARRY IN CHARLESTOWN, NEAR BRADFORD STATION, R. I.

Showing pegmatite dikes in the gneiss apparently starting from the granite surface; also sheet structure passing from granite into gneiss.

B. CARVING IN FINE QUARTZ MONZONITE, "BLUE WESTERLY" GRANITE, FROM THE NEW ENGLAND GRANITE WORKS QUARRY, WESTERLY, R. I.

N. 65° E., vertical, spaced 3 to 30 feet, forms the south wall; (*b*), strike north, vertical, forms east and west walls, and one on either side. The rift coincides with the foliation; the grain is horizontal, and the hard way vertical, east to west. The stone breaks somewhat readily along the hard way. There are dikes of aplite up to a foot thick, striking northwest. A small one of these has a central band of ilmenite 0.3 inch thick. The aplite (specimen D, XXX, 23, c), like that of the Oneco quarry, is of light cream-color and very fine texture, with particles under 0.1 inch. In a thin section they range from 0.05 to 1.12 millimeters. Its constituents, in descending order of abundance, are clear colorless quartz with cavities, microcline with orthoclase, oligoclase, minute and sparse biotite, with accessory ilmenite, garnet, and apatite. There is a 6-inch dike of smoky quartz with feldspathic border on the west side; also lenses of pegmatite with smoky quartz.

Transportation, by cart 1¼ miles to Oneco station.

The product is used for curbing, building, trimmings, chimney caps, and paving, which is sent to Providence. Specimens: Cranske Mill addition at Moosup, Conn.

The **Bennett quarries** are in Sterling Township, three-fourths mile east of Sterling station and about 1¼ miles west of the Rhode Island line. Operator, Nelson A. Bennett, Sterling. Idle since 1914.

The granite (specimens D, XXX, 24, a, d, e, Sterling granite gneiss, No. 24 of the State preliminary geologic map) is a biotite granite gneiss of general light pinkish-gray color, with conspicuous black streaks on the foliation face, and of fine-grained, obscurely plicated, gneissic, much elongated porphyritic texture. It is marked by long, tapering parallel lenses from 0.1 to 0.3 inch wide consisting of quartz or feldspar or mica. The rock has very different aspects on its rift, grain, and hard-way faces. The rift or foliation face (specimen a) shows the lenses of black mica, pink feldspar, and smoky quartz. Along the grain (specimen a, smallest side), which is vertical to the foliation but parallel to the lenses, the mica is in very thin streaks, while along the hard way (specimen e), which is at right angles to the lenses, the rock is mottled with pink, gray, and black. The feldspar particles are up to 0.2 inch. The constituents, in descending order of abundance, are light-pinkish potash feldspar (microcline and orthoclase), slightly kaolinized; light smoky quartz, with cavities in irregular sheets; cream-colored soda-lime feldspar (oligoclase-albite), somewhat kaolinized; biotite (black mica); and very little hornblende. Accessory: Allanite, apatite, zircon. Secondary: Calcite, kaolin. Slight effervescence with muriatic-acid test.

A more pinkish granite (specimen 25, a), from a point about 1½ miles north-northeast of Sterling station, a little north of Quaduck Brook, is of identical texture and composition, but the feldspars are more pinkish and more altered, the oligoclase-albite being much kaolinized and carrying calcite.

These stones are well adapted for the manufacture of paving blocks on account of their marked rift and grain and their smooth fracture along the hard way. The contrasts of shade and color in the fresh rock and its foliation make it suitable and attractive for other uses.

The quarry, if such it can be called, is part of a boulder train about 1½ miles from north to south by one-half a mile in width, consisting of boulders of one gneiss, which range from 5 to 30 feet in diameter and correspond to the underlying gneiss of the region. Indeed, a few of the quarried "boulders" are the weathered tops of ledges. The quarry there is, in the quarrymen's sense, a "boulder quarry."

Rock structure: A ledge of the gneiss, 30 feet high, shows the gneiss foliation, striking north and dipping 55°–70° W. Sheets 2 to 5 feet thick dip 25° N. 70° W., and vertical joints strike east and are spaced 1 to 10 feet. The rift coincides with the foliation, and the grain is at right angles to it but parallel to the lenses. Slight discoloration extends 10 inches from the surface.

Transportation, by cart to a 200-foot siding one-quarter mile east of Sterling station.

The product is used for curbing, sills, caps steps, buttresses, underpinning, and paving. The paving, which is the chief product, finds a market in Providence. The operator pays a royalty to the landowners on the boulders he splits up.

The **Sterling quarry**, an abandoned quarry three-fifths mile east-southeast of Sterling station, in the same township, is of interest because of the texture of its stone.

The granite (specimen D, XXX, 26 a) is a biotite granite gneiss of medium, inclining to dark bluish-gray color and of fine gneissic texture, with fine matrix (particles under 0.2 inch) and porphyritic feldspars up to 0.5 inch. Its constituents are the same as those of the Bennett boulders, but the potash feldspar is bluish, the quartz clear and colorless, and the oligoclase milk-white to buff or faintly pinkish. The porphyritic texture is less obscured by elongation, and the biotite, while in parallel arrangement, is evenly distributed, as is also the quartz. Titanite is among the accessory minerals. This gneiss evidently originated in the same granite as that of the Bennett boulders but is less metamorphic—that is, its minerals have not been redistributed to the same extent, nor have its feldspars been subsequently so greatly altered.

Rock structure: The gneiss foliation strikes north and dips 70° W. to 90°, and the sheets are from 6 inches to 3 feet thick.

WINDHAM.

The **Larrabee quarry** is in Windham Township, three-fourths mile northwest of the Willimantic railroad station. Operator, Charles Larrabee, jr., R. D. 2, Willimantic. Idle since 1915.

The granite (specimens D, XXX, 27, a, b, d, Willimantic gneiss, No. 25, of the State preliminary geologic map) is a biotite granite gneiss of interbanded medium and very dark gray shades, with a few pinkish bands of muscovite gneiss and some of pinkish pegmatite. Its texture is fine-grained gneissic, with an unplicated lamination and particles under 0.1 inch, the feldspars in the pegmatite bands up to 0.3 inch. The constituents of the medium-gray bands, in descending order of abundance, are translucent potash feldspar (microcline, partly kaolinized, and orthoclase); light smoky quartz with some cavities; whitish soda-lime feldspar (oligoclase or oligoclase-andesine), some of it kaolinized and micacized and with calcite, also intergrown with quartz more or less circular in cross section; biotite (black mica), some of it chloritized; and a little muscovite or bleached biotite. Accessory: Garnet (fifth in order of abundance), magnetite, pyrite, apatite, zircon, titanite. Secondary: Kaolin, a white mica, calcite, chlorite. Much quartz is in lenses 0.28 by 2.24 millimeters. There are many fine particles of quartz and feldspar between the larger ones. In some specimens garnets are so abundant as to make minute pinkish bands. No effervescence with muriatic-acid test.

A thin section of a pinkish (not pegmatitic or garnetiferous) band shows the same potash feldspar, pinkish and much kaolinized, light smoky quartz, much altered oligoclase-andesine, and muscovite instead of biotite, with allanite

among the accessories. This is a muscovite gneiss. The very dark bands are due to more abundant biotite.

The quarry, opened about 1878, measured in 1908 about 300 feet from east to west by 150 feet across and 40 feet in depth.

Rock structure: The gneiss foliation strikes east and dips 10° S. The sheets, 6 to 12 inches thick, coincide with the foliation. There are three sets of joints—(a), strike N. 40° E., vertical, spaced 2 to 8 feet, coated with quartz; (b) strike N. 5° E., vertical; (c), strike N. 80° W., vertical, spaced 20 feet. The rift coincides with the foliation, but the grain is vertical, north to south, and difficult, and the hard way more so. Pegmatite and smoky quartz veins up to 2 feet thick coincide with the foliation and some with joints (b) and (c). Some small pegmatite dikes carry a little apatite.

Transportation, by cart three-fourths mile to Willimantic.

The product is used for curbing, crosswalks, steps, and flagging, for which its uniformly straight foliation and its great toughness in transverse directions well adapt it.

RHODE ISLAND.

The granite industry of Rhode Island centers at Westerly. Some of the quarries are near Westerly, others near Bradford station in the same township, and some in Charlestown. Westerly is at the extreme western edge of the State, 5 miles north-northeast of Watch Hill, on the Atlantic shore, and Niantic is 4½ miles east-northeast of Westerly. (See Stonington and Charlestown topographic maps, U. S. Geol. Survey, and fig. 92.)

WASHINGTON COUNTY.

WESTERLY AND CHARLESTOWN.

TOPOGRAPHY.

Some of the Westerly quarries are on an east-west ridge about a mile northeast of the city. This ridge attains an elevation of 200 feet above sea level, or 160 feet above the city. Others are about a mile southeast of Westerly on the 130-foot level, and one lies a mile east of it on the 100-foot level. The quarries formerly known as "The Niantic" lie from a mile south-southeast to 1¾ miles southeast of Bradford station, some being in the town of Westerly, and one in the town of Charlestown. (See fig. 92.)

GEOLOGIC RELATIONS.

The granites of Westerly and Charlestown have been briefly described by Merrill,[73] by Kemp[74] and by Rice and Gregory,[75] and in Gregory and Robinson's geologic map of Connecticut,[76] reproduced in Plate XXVIII, the granite gneiss area into which the Westerly granites were intruded in the adjacent parts of Connecticut is shown.

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[73] Merrill, G. P., Report of building stones: Tenth Census, vol. 10, p. 20, 1885.

[74] Kemp, J. F., Granites of southern Rhode Island and Connecticut, with observations on Atlantic coast granites in general; Geol. Soc. America Bull., vol. 10, pp. 361–382, especially pp. 365–370, 375, 376, and pl. 35, 1899.

[75] Rice, W. N., and Gregory, H. E., Manual of the geology of Connecticut: Connecticut State Geol. and Nat. Hist. Survey Bull. 6, pp. 115, 136, 152, 154, 155, 1906.

[76] Gregory, H. E., and Robinson, H. H., Preliminary geological map of Connecticut, Sterling granite gneiss (24), also the accompanying Outline of the geology of the State: Connecticut State Geol. and Nat. Hist. Survey Bull. 7, p. 36, 1907.

According to these geologists, the "pink" and "blue" fine-grained Westerly granites were intruded as dikes in a molten state into certain older granite gneisses (Sterling granite gneiss), which form extensive parts of the surface

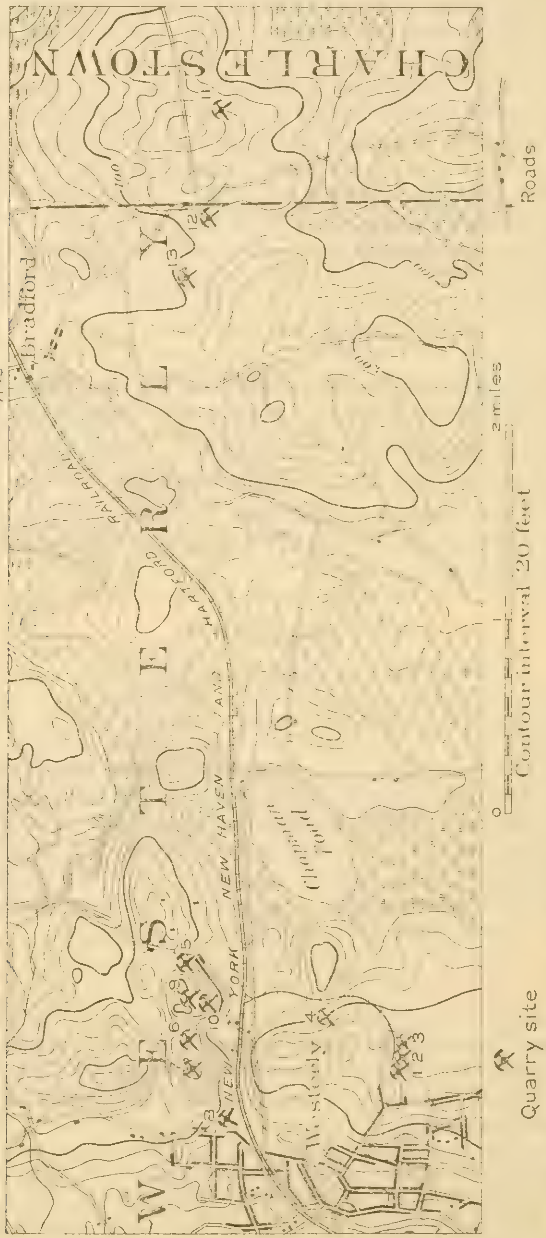

FIGURE 92.—Map of parts of Westerly and Charlestown, R. I., showing location of granite quarries. 1, New England; 2, Smith east; 3, Smith old opening; 4, Catto; 5, Redstone; 6, Smith north; 7, Calder & Carnie; 8, Dixon; 9, Frazer; 10, Chapman; 11, Klondike; 12, Newall; 13, Crumb.

along the Atlantic shore. The medium-grained reddish granite of the Redstone quarry, northeast of Westerly, and the very coarse gneisses exposed at the other quarries all belong to this granite gneiss formation. These granite

gneisses were originally granites which had likewise been intruded into an earlier overlying gneiss, a metamorposed sedimentary rock (Putnam gneiss, etc.), of which no remnants are reported as occurring at Westerly. Prior to the intrusion of the Westerly granite these older granites had been subjected to an amount of lateral compression sufficient to crush, elongate, rearrange, and recrystalize their particles and thus change them into gneiss. The amount of this change is not always uniform. At some time prior to the intrusion of the Westerly granite the granite gneiss was traversed by pegmatite dikes.

The Westerly granites themselves were later also traversed by pegmatite dikes and still later by basic dikes. These dikes are probably of Triassic age, as are the trap ridges of New Haven and the Connecticut Valley. Thus the Westerly region bears records of at least five periods of igneous activity.

In the geologic map of Massachusetts and Rhode Island compiled by Emerson [77] the Sterling granite gneiss area extends from Westerly eastward to Narragansett Pier and northward along the Connecticut border to the latitude of Pawtucket.[78]

GEOLOGY OF WESTERLY AND CHARLESTOWN QUARRIES.

That the fine pink granite is of later date than the coarser red granite (Sterling granite gneiss) is clear from their relations at the Redstone, Smith north, and Calder & Carnie quarries. That the red granite itself is older than a banded biotite gneiss follows from its containing inclusions of it. Northeast of Westerly the pink granite was intruded into the red granite, but at the Smith and Catto quarries (fig. 18) it or its associated fine blue granite was intruded into a finely banded biotite gneiss not unlike that in the red granite, and at the Klondike, Newell, and Crumb quarries, near Bradford station (Pl. XXXIV, *A*, and fig. 93), it was intruded into a porphyritic biotite gneiss which may be simply a more gneissic phase of a coarser Sterling granite gneiss than that exposed at the Redstone and Dixon quarries. But the finely banded gneiss of the other quarries and of the inclusions resembles the inclusions in the "Redstone granite" and differs from that granite itself both by the absence of microcline and by the predominance of oligoclase or of oligoclase-andesine to andesine, so as to indicate that these finely banded gneisses belong to another formation, possibly to the Putnam gneiss of Connecticut geologists. At the Smith quarry the strike of the banded biotite gneiss is N. 35° W.

The fine Westerly granites appear in dikelike masses from 50 to 150 feet thick, striking N. 75°–90° W. and dipping 30°–45° about south. At the Smith quarry they are underlain by a parallel mass of aplitic granite of similar character, carrying also inclusions of finely banded biotite gneiss. At the Klondike quarry the granite has a flow structure striking N. 10°–20° W., intersecting the course of the apparent dike. It is uncertain whether these are granite dikes or protuberances from a broad intrusive mass which have become exposed by the erosion of the thinner parts of the overlying gneiss.

The phenomena at the quarries indicate the following as the probable order of geologic events about Westerly: (1) A finely banded biotite gneiss forms the surface; (2) intrusion by the red granite of the hill northeast of Westerly with a northeasterly flow structure, and also by the gray granite near Bradford station; (3) metamorphism of the red and gray granite converting it

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[77] See U. S. Geol. Survey Bull. 597, pl. 10, p. 230, 1916.

[78] See also Loughlin, G. F., Intrusive granites and associated sediments in southwestern Rhode Island: Am. Jour. Sci., 4th ser., vol. 29, pp. 447–457, 1910; The gabbros and associated rocks at Preston, Conn.: U. S. Geol. Survey Bull. 492, 1912.

into a porphyritic gneiss (Sterling granite gneiss); (4) intrusion of the fine granites of Westerly and Charlestown, in some places into the earlier banded biotite gneiss, in others into the more or less altered Sterling granite gneiss; (5) pegmatite and aplite dikes traverse both the westerly granites and the Sterling granite gneiss, though some of the latter are connected with the intrusion of the finer granite; (6) a diabase dike, probably Triassic, traverses both the Westerly and the Sterling granite and the pegmatite dikes in the latter at the Redstone quarry.

The chief joint course in the fine granites is N. 10°–25° E., but the following also occur: N. 35°–40° E., N. 50°–60° E., N. 10°–22° W., N. 45°–55° W. In the older red granite the courses are N. 35°–45 E. and N. 60° W. The rift in the fine granite is reported as either horizontal or inclined 10° N. or S., and the grain as either vertical or 75° N., with an east-west or N. 65° W. or N. 70° E. course, in one instance with a dip of 45° S. 20–W., in another with a scarcely perceptible dip. The rift in the coarser granite is reported as dipping 20° E. or W. A compressive strain is reported as being from north and south, east and west, and northeast and southwest.

WESTERLY GRANITES.

The following summarizes the more detailed descriptions of specimens and thin sections, from both Westerly and "Niantic" (Charlestown) quarries, given on pages 408–414.

"Westerly pink," sometimes called "Westerly statuary" granite is a quartz monzonite of more or less pinkish or buff medium-gray color, and of very fine, even-grained texture, with slender feldspars not over 0.1 inch long and slender micas not over 0.15 inch long. Its constituents, in descending order of abundance, are pale smoky quartz; clear colorless to milk-white soda-lime feldspar (oligoclase-albite to oligoclase); in nearly equal amount, slightly pinkish or cream-colored potash feldspar (microcline and orthoclase); and black mica. Magnetite and pyrite are among the accessory minerals, and calcite is among the secondary.

"Blue Westerly" granite is a quartz monzonite of more or less bluish medium-gray color, with fine black particles, and of fine, even-grained texture, with feldspars up to 0.1 or 0.2 inch and mica to 0.1 or 0.15 inch long. Its constituents, in descending order of abundance, are clear to milk-white, pinkish, or cream-colored soda-lime feldspar (oligoclase-albite to oligoclase); more or less transparent bluish or greenish potash feldspar (microcline and orthoclase); and black mica. Magnetite and pyrite are among the accessory minerals, and calcite is among the secondary.

"Red Westerly" granite is a biotite granite of reddish-gray color speckled with black and of even-grained medium, inclining to coarse texture, with feldspars under 0.4 inch, exceptionally 0.5 inch, and mica up to 0.2 inch long. Its constituents, in descending order of abundance, are reddish potash feldspar (microcline and orthoclase); smoky quartz; cream-colored striated soda-lime feldspar (oligoclase-albite); and black mica. Both feldspars are in places stained red from hematite, resulting from the oxidation of magnetite particles, which with pyrite is among its accessory minerals. Secondary calcite.

Estimates of the mineral percentages in the pink granite, obtained by applying the Rosiwal method to camera lucida drawings of parts of two thin sections enlarged 40 diameters, yield the following results, with mesh of 1 and 1.4 inches and total linear lengths of 40 and 33.6 inches.

Estimated mineral percentages in "Westerly pink" granite.

Quartz	36.09
Oligoclase-albite to oligoclase (soda-lime feldspar)	30.63
Microcline and orthoclase (potash feldspar)	28.44
Biotite (black mica)	3.59
White mica	.50
Magnetite	.75
	100.00

The average diameter of the particles, obtained by the same measurements, is 0.175 millimeter, or 0.0069 inch. Measurements of the larger particles in four thin sections of this granite, made with the micrometer, give the following figures: Microcline and orthoclase 0.50 to 0.95 millimeter, oligoclase 0.56 to 1.122 millimeters, biotite 0.39 to 0.56 millimeter, white mica 0.168 to 0.392 millimeter, quartz 0.50 to 1.122 millimeters, magnetite 0.112 to 0.224 millimeter. The feldspars, quartz, and biotite in their coarser particles thus range from 0.39 to 1.122 millimeters, or 0.015 to 0.0439 inch.

Two estimates of the mineral percentages in "Westerly blue" granite (pp. 409, 416), made in the same way, average:

Estimated mineral percentages in "Westerly blue" granite.

Soda-lime feldspar (oligoclase-albite to oligoclase)	44.48
Quartz	25.28
Potash feldspar (microcline 11.03, orthoclase 9.26)	20.29
Biotite (black mica)	5.90
White mica	1.53
Magnetite	1.16
Pyrite	.05
Allanite and apatite	1.31
	100.00

The average diameter of the particles obtained by the application of the same method to three "Westerly blue" granites, is 0.0099 inch, or about 50 per cent larger than that of the statuary.

An estimate of the mineral percentages in "red Westerly" granite will be found on page 413.

Kemp[79] gives two analyses of Westerly granite made by F. W. Love, then of Cornell University, which are repeated here for reference.

Analyses of Westerly granites.

	Gray granite.	Red granite.
SiO_2 (silica)	71.64	73.05
Al_2O_3 (alumina)	15.66	14.53
Fe_2O_3 (iron sesquioxide) FeO (iron oxide)	2.34	2.96
MnO (manganese oxide)	Trace.	Trace.
CaO (lime)	2.70	2.06
Na_2O (soda)	1.578	1.72
K_2O (potash)	5.60	5.39
H_2O (water)	.482	.29
	100.00	100.00

[79] Kemp, J. F., Granites of southern Rhode Island and Connecticut, with observations on Atlantic coast granites in general: Geol. Soc. America Bull., vol. 10, p. 375, 1899.

Kemp gives 2.654 as the specific gravity of the gray analyzed.

Messrs. Sullivan and Schaller, chemists, of this Survey, find that five specimens of Westerly granites contain the following percentages of CaO (lime) soluble in hot dilute acetic acid, which indicate the presence of the percentages of $CaCO_3$ (calcium carbonate) shown in the second column. All these granites effervesce slightly with muriatic-acid test.

Lime and calcium carbonate in Westerly granite.

	CaO.	$CaCO_3$.
White statuary (pink Westerly)	0.34	0.6
Blue Westerly	.176	.312
Red Westerly	.25	.446

The "pink" (really buff to slightly pinkish gray) and the "blue" (really bluish gray) Westerly granites are strictly monumental granites, but the former has been called a statuary granite, as it lends itself to the most delicate carvings. The fineness of its texture becomes more apparent in comparing it with that of statuary marbles. As compared with European marbles its texture is between that of "Carrara ordinary" and "Laas statuary" of Tyrol. As compared with American marbles it corresponds to the dolomite of Lee, Mass., and the "Brandon Italian" of Vermont. On the table of grades of marble texture[80] it falls in grade 4, medium. It takes a high polish, and its hammered surface is light, offering, as quartz monzonites generally do, a marked contrast of shade to the polished surface.

Although "blue Westerly" granite (marble, grade 5, coarse) is 50 per cent coarser in texture than the "pink Westerly," it lends itself well to monumental and sculptural work, as is shown by Plate XXXIV, *B*. Its polish is not quite so high as that of the "pink," owing to the larger size of its mica scales, but its contrast of shade is equally strong.

"Red Westerly" granite is used only for construction.

QUARRIES.

The New England quarry is 0.9 mile southeast of the Westerly station and 100 feet above it. (See fig. 92.) Operator, New England Granite Works, Westerly.

The granite is of two varieties. One (specimens D, XXVIII, 1, f, i), "pink Westerly," is a quartz monzonite of very slightly pinkish medium-gray color, and of very fine, even-grained texture, with very slender feldspars not over 0.1 inch long and slender mica scales rarely 0.1 or 0.15 inch long. The average diameter of all its particles, including the magnetite, as determined by the Rosiwal method, is 0.0069 inch, or 0.175 millimeter, as given on page 407. Its constituents, in descending order of abundance are pale smoky quartz with hairlike crystals of rutile and a few cavities; clear colorless to milk-white soda-lime feldspar (oligoclase-albite to oligoclase), partly kaolinized and micacized; in almost equal amount, slightly pinkish or cream-colored potash feldspar (microcline and orthoclase), some of it intergrown with quartz circular in cross section; biotite (black mica), some of it chloritized and interleaved with white mica or else partly bleached; some separate muscovite may be present also. Accessory: Magnetite (ilmenite?), titanite, pyrite, allanite, apatite, zircon, rutile. Secondary: Kaolin, one or two white micas, chlorite, carbonate.

[80] See Dale, T. N., and others, The commercial marbles of the southern Appalachian region: U. S. Geol. Survey Bull. — (in preparation).

Estimates of mineral percentages in this stone have been given on page 407. W. T. Schaller, chemist, of this Survey, finds that it contains 0.34 per cent of CaO (lime) soluble in hot dilute acetic acid, which indicates a content of 0.6 per cent $CaCO_3$ (calcium carbonate). The presence of calcite is shown by the microscope and by a slight effervescence with muriatic-acid test.

A compression test made for the firm at the United States arsenal at Watertown, Mass., in 1907, with a cube of about 2-inch face, gave this granite an ultimate compressive strength of 39.750 pounds to the square inch (direction of rift or grain with reference to pressure not noted).

The sculptural qualites of this stone have already been dwelt upon. The polished face shows minute particles of magnetite and a few of pyrite. It hammers light gray, and the contrast between this and the shade of the polished face is somewhat marked.

The second variety (specimens D, XXVIIII, 1, c, cc), "blue Westerly," is a quartz monzonite of very slightly bluish medium-gray color with fine black particles. Its texture is even grained, fine, with feldspars up to 0.2 inch and mica to 0.15 inch. Its constituents, in descending order of abundance, are: Clear to milk-white or pinkish soda-lime feldspar (oligoclase-albite to oligoclase), much of it kaolinized and micacized; pale smoky quartz with a few needle-like crystals, probably of rutile, and with cavities in sheets; clear to blue-greenish and grayish potash feldspar (orthoclase and microcline), intergrown with quartz, circular in cross section, and slightly micacized; biotite (black mica), some of it chloritized, and with needle-like crystals of rutile (?); and muscovite or bleached biotite. Accessory: Magnetite (ilmenite?), pyrite, apatite, allanite, zircon, rutile. Secondary: Kaolin, two white micas, chlorite, carbonate, rarely hematite and epidote.

An estimate of the mineral percentages, obtained by applying the Rosiwal method to a camera lucida drawing of part of a thin section enlarged 40 diameters, yields the following results with a mesh of 1.7 inches, and total linear length of 42 inches:

Estimated mineral percentages in "blue Westerly" granite from the quarry of the New England Granite Works.

Quartz	21.15
Soda-lime feldspar (oligoclase-albite to oligoclase)	52.64
Potash feldspar (microcline 4.14, orthoclase 10.5)	14.65
Biotite (black mica)	5.52
White mica	3.05
Magnetite	1.71
Allanite	1.28
	100.00

No great value need to be attached to the figures for allanite, as a shifting of the mesh would have thrown it out altogether.

The average diameter of the particles obtained by the same method is 0.0112 inch.

E. C. Sullivan, a chemist of this Survey, finds that this stone contains 0.20 per cent of CaO (lime), soluble in hot dilute acetic acid, which indicates a content of 0.35 per cent of $CaCO_3$ (calcium carbonate). The presence of calcite is also shown by the microscope and by a very slight effervescence with muriatic-acid test.

A compression test made for the firm at the United States arsenal at Watertown, Mass., in 1907, with a cube of about 2-inch face, gave it an ultimate com-

pressive strength of 31,970 pounds to the square inch (direction of rift or grain with reference to pressure not noted).

This stone takes a high polish, but the mica scales, being a little larger than in the "pink," show more on the surface. The polished face shows not a little magnetite in fine particles, with rare grains of pyrite. The combination of a slightly bluish with a slightly pinkish feldspar, both in fine particles, results in a peculiar gray in the polished face. The hammered face is light gray and in contrast to the shade of the polished surface.

The quarry, opened about 1860, measured in 1906 about 300 feet in a west-northwest direction by 200 feet across and from 40 to 80 feet in depth. Within 20 feet west-northwest of it is another opening of about the same size, to be united with the main opening, so as to obtain a working face 600 feet long.

Rock structure: The sheets, 6 inches to 12 feet thick, are horizontal but somewhat irregular, owing to "growing on." There are two sets of joints—(a), strike N. 15°–25° E., vertical, spaced 8 inches to 30 feet, forms a heading 15 to 20 feet wide on the west side, separating it from the older excavation, and another, 5 to 10 feet wide, on the east side, which divides this from the adjacent Smith quarry; (b), strike N. 50°–55° W., vertical, spaced 18 inches to 30 feet. The rift is reported as horizontal, and the grain as vertical, with N. 65° W. course. There is a 2-inch pegmatite dike striking N. 37° E., consisting of pink potash feldspar, amethystine quartz, and muscovite; the feldspar is partly altered to light-green epidote. Pegmatite dikes also traverse the heading on the west side. Rusty stain is 1 to 7 inches thick on the sheet surfaces. There is much kaolinization of feldspar and limonite stain adjacent to the pegmatite dikes. On the south-southwest wall the granite is in contact with a southward inclined overhanging mass of dark biotite gneiss with a vertical foliation. This is also crossed by pegmatite dikes. The line of contact between granite and gneiss is jagged in places. The relations on the north wall are now largely concealed by dumps, but their character is well exposed in the adjoining Smith quarry, as described on page 411. The structural relations of the pinkish-gray and bluish-gray granite to each other are not clear. At one point on the south-southwest wall the former seems to underlie the latter, and there seem to be also lateral changes in the color of both near the dike which are possibly caused by it. The width of the granite from north-northeast to south-southwest, at right angles to the dip, does not exceed 150 feet.

Transportation, by siding to New York, New Haven & Hartford Railroad.

Nearly all of the product is used in monumental work, the rest in buildings, and the waste for paving, particularly small blocks for electric roads. Specimen monuments of the "blue": National monument, Gettysburg, Pa.; Antietam monument, Maryland; Perkins monument, Akron, Ohio; Skinner and Ware monuments, Denver, Colo.; of the "pink": Horne monument, with a 7-foot 6-inch figure, Homewood cemetery, Pittsburgh, Pa.; Whiton monument, Greenwood cemetery, Brooklyn, N. Y. Plate XXXIV, *B*, shows lilies and passion flowers on the base of a cross of the "blue" stone. Specimen buildings of the "blue": Connecticut Mutual Insurance Building, Hartford; Branford House, Groton, Conn.; Mutual Life Insurance Building, Philadelphia; Williamsburg Savings Bank, Brooklyn, N. Y.

The **Smith quarry** adjoins on the east the one just described and is about 0.9 mile southeast of Westerly station and 100 feet above it. (See fig. 92.) Operator, Smith Granite Co., Westerly.

The granite consists of the identical two varieties, "Westerly pink" and "Westerly blue," already described under the New England quarry. Both are quartz monzonites—the pink a slightly pinkish medium-gray of even-

grained, very fine texture; the blue a slightly bluish medium-gray of even-grained, fine texture. (For full descriptions see pp. 408–409.)

The quarry, first opened in 1846, consists of two openings. The "New East quarry," separated from the New England quarry only by a heading measured in 1906 250 feet east-southeast by 200 feet across and 65 feet deep; the other, older one, contiguous to the last on the east, was about 400 feet east-southeast by 125 feet across and 150 feet deep.

Rock structure: The sheets in the upper 25 feet are from 2 inches to 2 feet thick, and below that from 9 inches to 5 feet thick, and all horizontal. There is only one set of joints, strike N. 20°–22° E., spaced 100 to 300 feet, forms a 50-foot heading between the two openings and a 5 to 10 foot heading between the western opening and the New England quarry. The rift is reported as horizontal, and the grain as vertical, with a N. 65° W. course. On the south-southwest the granite is overlain by a mass of dark-gray banded biotite-hornblende gneiss of somewhat fine texture, which strikes N. 30° W. and dips 45° SSW. The rock contains much soda-lime feldspar (oligoclase-andesine to andesine) but no microcline. On the north-northeast the granite is apparently underlain at 45° by a mass of granite (quartz monzonite) of more or less pinkish-gray color and of somewhat fine texture with a variable amount of black mica, so as in places to resemble an aplite. It is also marked in places by dark-brownish stains, 0.25 inch in diameter and an inch or so apart, which are due to the alteration of allanite particles into hematite and limonite. This rock contains many angular inclusions, large and small, of a somewhat finely banded biotite gneiss, which itself contains lenses and dikes of pegmatite parallel to its schistosity and evidently formed before the intrusion of the quartz monzonite. The foreman stated that the "blue granite" at the bottom of the larger opening contained an inclusion 10 feet in diameter like the inclusions of gneiss above described. In this opening about 40 feet of "pink" intervenes between the overlying gneiss and the "blue," but in the smaller opening these relations are reversed. The entire width of the mass of "blue" and "pink" appears to be 80 to 100 feet, measured at right angles to its inclination. The heading which separates the two openings is much broken by subjoints parallel to it. For a thickness of 8 feet on the west it is altered to a dull greenish-reddish color. In thin section this shows the feldspars kaolinized, micacized, and chloritized, most of the biotite bleached, the magnetite passing into hematite and the pyrite into limonite. As its soda-lime feldspar is oligoclase-andesine, differing from that of the adjacent granite, this heading may be a transverse granite dike. These structural data were obtained in 1906.

Transportation, by siding to New York, New Haven & Hartford Railroad, but paving stones are carted one-third mile to wharf on Pawcatuck River.

The product is nearly all used for monuments; the waste goes into paving blocks of various sizes. Specimen monuments: Equestrian statue of Washington erected by the United Order of American Mechanics at Allegheny, Pa.; Roger Williams monument at Roger Williams Park, Providence, R. I.; First Massachusetts Volunteer Infantry monument, Gettysburg, Pa.; Ohio State monument, Vicksburg, Miss.; soldiers' monument, Jewett City, Conn.; of the "pink," C. A. Roebling monument, Trenton, N. J.

The **Calder & Carnie quarry** is 0.9 mile N. 50° E. from the Westerly station, and 160 feet above it, on the western hump of the ridge north of the railroad. (See fig. 92.) Operator, Smalley Pink & Red Westerly Co., Westerly.

The granite (specimen D, XXVIII, 8, a), "Westerly pink," is a quartz monzonite of medium pinkish-buff gray color, more pinkish than any of the other fine Westerly granites except specimen I, e, from the rock next to the peg-

matite dike in the New England quarry. Its texture is even grained, very fine, with feldspars not over 0.1 inch and mica still less. Its constituents are the same as those of the fine stone from the Smith north quarry, but with a little more hematite stain. The thin section shows carbonate, and the stone effervesces slightly with muriatic-acid test. The quarry also yields the "red" constructional granite described on this page.

The quarry, first opened in 1882, measured in 1906 about 400 by 250 feet and 90 feet deep.

The sheets, 6 inches to 8 feet thick, are horizontal and irregular. There are two sets of joints—(a), strike N. 20° W., dip 45° S. 70° W., spaced 2 to 8 feet, discontinuous, forms a heading 10 feet wide in the center, and one of these joints has subjoints striking N. 30° W., one-half to 1 inch apart; (b), strike N. 35°–40° E., dip 80° N. 37° W., and 90°, spaced 2 to 8 feet. The rift is reported as dipping north at a low angle, and the grain as striking N. 70° E. and dipping 45° E. 20° W. The fine granite occurs here as a dike dipping 45° S. and 50 feet thick, with the medium-grained "red" on both sides of it. It also contains pegmatite dikes parallel to its course. Some fine veins in the flow direction are described on page 22. Along joints (a) the granite is much reddened for 1 to 2 inches. In this reddish zone the feldspars are much kaolinized and micacized, the biotite is chloritized, epidote occurs, and the magnetite is altered to hematite, which has reddened the feldspars. Rusty stain is up to 4¾ inches thick on sheet surfaces.

Transportation, by cart three-fourths mile to siding of New York, New Haven & Hartford Railroad.

The product is used for monuments and buildings.

The **Catto quarry** is about a mile east-southeast of Westerly station, 60 feet above it, and half a mile northeast of the Smith and New England quarries. (See fig. 18.) It is now abandoned.

The granite (specimen D, XXVIII, 9, a), "blue Westerly," is a quartz monzonite of very slightly bluish medium-gray color with fine black particles. It is a trifle more bluish than that of the New England quarry. Its texture is fine, with feldspar and mica up to 0.1 inch, the former exceptionally 0.16 inch. It is thus a trifle finer than specimens 1, c, cc (p. 409), but its constituents are the same.

The quarry, opened before 1886, measured in 1906 about 350 feet east-west by 200 feet across and from 75 to 100 feet in depth.

Rock structure: The sheets, 6 inches to 10 feet thick, dip north at a low angle. But one set of joints strike N. 22° W., vertical, spaced 3 to 50 feet, and discontinuous below. The rift is reported as horizontal and the grain as scarcely perceptible. The east face of quarry shows the relations of the granite to overlying banded gneiss.

The **Redstone quarry** is less than 1½ miles east-northeast of Westerly station, at the east foot of an east-west ridge, one-fourth mile north of the New York, New Haven & Hartford Railroad. (See fig. 92.) Operator, New England Granite Works, Westerly.

The chief granite of this quarry (specimens D, XXVIII, 2, b, h), "red Westerly," is a biotite granite of medium reddish-gray color speckled with black. Its texture is even grained, medium, inclining to coarse, with feldspars under 0.4 inch, exceptionally 0.5 inch, and mica up to 0.2 inch. Its constituents, in descending order of abundance, are reddish potash feldspar (microcline and orthoclase), some of it slightly micacized, intergrown wtih quartz in vermicular structure, in places also with soda-lime feldspar; smoky quartz with hairlike crystals, probably of rutile, also with cavities in sheets with rift cracks parallel to them; cream-colored striated soda-lime feldspar (oligoclase-albite), kaolin-

ized and micacized, and intergrown with quartz like the other; and biotite (black mica), some of it bleached. Accessory: Magnetite, pyrite, apatite, zircon, rutile. Secondary: Kaolin, two white micas, hematite stain from magnetite particles, in places reddening both feldspars, calcite.

An estimate of the mineral percentages by the Rosiwal method yields the following results with a mesh of one-half inch and total linear length of 33½ inches: Potash feldspar (microcline and orthoclase), 35.40; quartz, 29.87; soda-lime feldspar (oligoclase-albite), 28.35; biotite (black mica), 6.74.

An analysis of this granite by Love has been given on page 407.

W. T. Schaller, chemist, of this Survey, finds that it contains 0.25 per cent of CaO (lime) soluble in hot dilute acetic acid, which indicates a content of 0.446 per cent of $CaCO_3$ (calcium carbonate), the presence of which is shown by the microscope and also by a slight effervescence with muriatic-acid test.

A compression test made for the firm at the United States arsenal at Watertown, Mass., in 1907, with a cube of about 2-inch face, showed the first crack with 106,000 pounds and final fracture with 113,000 pounds, indicating an ultimate compressive strength of 28,540 pounds to the square inch (direction of rift of grain with reference to pressure not noted).

The contrasts between the colors of the two feldspars come out strongly on the polished face, which shows considerable magnetite and some pyrite. The size of the mica plates is not favorable to the durability of the polish in long-continued outdoor exposure. It is a constructional granite of warm tint.

The quarry, opened in 1880, measured in 1906 about 850 feet from north to south by 250 feet across, with a working face 100 feet high on the west.

Rock structure: The sheets, 1 to 20 feet thick, are somewhat irregular. In the upper part most of them dip 10° about west-northwest and a few are horizontal, but lower down all are horizontal. At the south end the sheets are intersected by sharply curved partings ("toenails"). There are inclusions of finely banded biotite gneiss resembling the capping at the Smith and Catto quarries. The rift is reported as horizontal and the grain as fairly defined and vertical, with a N. 20° E. course. There is but one set of joints, strike N. 35° E., dip 70° S. 35° E. to 90°, spaced 15 to 50 feet, forms a heading in the center of the quarry and a heading at the extreme north end which is 40 feet wide. A dike 5 to 19 feet thick runs the whole length of the quarry, with a dip of 10° S., consisting of alternating reddish aplite and coarse pegmatite (reddish feldspar, smoky quartz, and biotite), some of the surfaces of which are coated with iridescent drusy hematite. Beneath this almost horizontal dike is a mass of unknown extent of fine pinkish quartz monzonite like that at the Smith and New England quarries described on page 406. This reaches the surface at the north and south ends of the quarry. The ovoidal mass shown in Plate XXIX, *B*, and described on page 73, came from the 40-foot heading which crosses this quartz monzonite at the north end of the quarry. Small basic dikes are described on page 56. Rust stain on the sheet surfaces is up to 3, rarely 4, inches thick. A thin section of it shows both feldspars stained with limonite. It follows irregular cracks in the microcline and the quartz, as well as the boundaries between them. It proceeds in some cases clearly from the larger grains of magnetite and from biotite scales.

Transportation, by siding to New York, New Haven & Hartford Railroad.

The product is used entirely for buildings. Specimens: Southern Pacific Building, Houston, Tex.; Tuberculosis Hospital, New Haven, Conn.; town hall and courthouse, Westerly, R. I.; Elks' Memorial, Buffalo, N. Y.; American Exchange, American Tract Society, and Travelers Insurance Co. Buildings, New York City.

The **Smith North quarry** is a mile N. 60° E. of the Westerly station, 120 feet above it, in a saddle on the east-west ridge north of the railroad. (See fig. 92.) Operator, Smith Granite Co., Westerly.

The granite is of two sorts—"red Westerly," a medium-grained biotite granite of medium reddish gray color identical with that of the Redstone quarry (specimens D, XXVIII, 2, b, h), described on page 412, and "pink Westerly" (specimen D, XXVIII, 4, a), a quartz monzonite of medium buff-gray color and of very fine, even-grained texture, with feldspars mostly up to 0.057 inch, exceptionally 0.1 inch, and mica to 0.028 ,exceptionally 0.15 inch. It is identical in composition with the "pink Westerly" described on page 408, but is of more pinkish tint.

The quarry, opened before 1892, measured in 1906 about 200 feet from east to west by 150 feet across, with a working face 75 feet high on the west and 25 feet on the east.

Rock structure: The sheets, 6 inches to 10 feet thick, are lenticular but very irregular and without uniform dip. The only set of joints strikes N. 10° E., vertical or nearly so, spaced 20 to 40 feet. The rift is reported as dipping 10° S., and the grain 75° N. Sixty feet of the fine granite overlies the "red," the plane of their contact dipping 40°–50° about south. At the top of the working face a pegmatite dike 10 feet thick dips 45° S. Rusty stain is only 2 inches thick on sheet faces.

Transportation, by cart one-fourth mile to New York, New Haven & Hartford Railroad.

Product: The "red" is used for buildings and the "pink" for monuments.

The **Dixon quarry** is about half a mile northeast of the Westerly station at the west foot of the east-west ridge north of the railroad. (See fig. 92.) It is now abandoned.

The granite (specimen D, XXVIII, 7, a) is a biotite granite of medium buff-gray color with fine black particles. Its texture is medium, inclining to coarse, with feldspars up to 0.4 inch, exceptionally 0.5 inch, and mica to 0.15 inch. Its constituents, in descending order of abundance, are pinkish-gray potash feldspar (microcline and orthoclase), slightly kaolinized and intergrown with quartz and soda-lime feldspar; smoky quartz with cavities; greenish-gray striated soda-lime feldspar (oligoclase-albite), some of it much micacized and kaolinized; and biotite (black mica), some of it chloritized. Accessory: Magnetite, pyrite, apatite, allanite, zircon. Secondary: Kaolin, two white micas, chlorite, limonite, hematite, carbonate.

This is a constructional granite which is closely related to the "red" of the Redstone quarry but in which the potash feldspars are less reddish and the soda-lime feldspars are greenish instead of cream-colored.

The quarry consisted in 1906 of three openings—one 150 by 100 feet and 20 to 40 feet deep, one 100 by 75 feet and 40 feet deep, and one 100 by 50 feet and 10 to 30 feet deep.

Rock structure: The sheets, 6 inches to 6 feet thick, are generally horizontal. There are two sets of joints—(a), strike N. 45° E., vertical, spaced 50 to 100 feet, forms several headings; (b), strike N. 60° W. vertical, spaced 50 feet and over, less numerous than (a).

Although the stone is adapted for buildings, only crushed stone was being produced in 1906.

The **Chapman quarry** is near the foot of the ridge. (See fig. 92.) It is abandoned, but is mentioned here because of its geologic features.

A joint face forming the west wall and working face strikes N. 10° W. It is intersected at intervals of 1 to 3 feet by vertical joints striking N. 50° E. At the top is an inclusion of biotite gneiss 10 feet in diameter. Dipping 10° S.

across this face is a pegmatite dike about a foot thick. Between 20 and 30 feet below it is an aplite dike a few inches thick with like dip. The sheets are only 1 to 3 feet thick, and the joint intervals are too short to make quarrying profitable. The granite is the fine-textured pinkish-gray quartz monzonite already described.

The **Klondike quarry** is in Charlestown, 1¾ miles southeast of Bradford station and 5¾ miles east of Westerly station. (See fig. 92.) Operator, Sullivan Granite Co., Westerly.

The granite (specimens D, XXVIII, 11, c, g), "blue-white Westerly," is a quartz monzonite of medium bluish-gray color with very fine black particles. Its texture is fine, with feldspars up to 0.1, exceptionally 0.2 inch, and mica to 0.05, exceptionally 0.1 inch. Its constituents, in descending order of abundance, are clear to milk-white or cream-colored striated soda-lime feldspar (oligoclase), partly kaolinized and micacized (in some crystals the altered part is central; in others it forms a zone with unaltered feldspar within and without it); slightly smoky quartz with hairlike crystals, probably of rutile, and very few cavities; more or less transparent bluish potash feldspar microcline and orthoclase, the first intergrown with quartz); and biotite (black mica), some of it chloritized. Accessory: Magnetite, titanite, pyrite rare, apatite, allanite, zircon, rutile. Secondary: Kaolin, a white mica, carbonate.

E. C. Sullivan, a chemist of this Survey, finds that this granite contains 0.18 per cent of CaO (lime) soluble in hot dilute acetic acid, which indicates a content of 0.32 per cent of $CaCO_3$ (calcium carbonate), the presence of which is also shown by the microscope and by a slight effervescence in muriatic-acid test.

A compression test made for the firm at the United States arsenal at Watertown, Mass., in 1907, with a cube of about 2-inch face, showed the first crack with 107,000 pounds and final fracture with 118,000 pounds, showing an ultimate compressive strength of 29,500 pounds to the square inch (direction of rift or grain with reference to pressure not stated).

This is a monumental granite of fine texture and bluish tint. Its texture is a little finer than that of the "blue" of the New England quarry and about the same as that of the stone from the Newall quarry (p. 416). It is more bluish than the former, not containing any pinkish feldspar, and, its mica particles being finer, it takes a higher polish. The polished face shows magnetite in fine particles, but scarcely any pyrite. There is a considerable contrast of shade between the hammered and polished faces.

The quarry, opened in 1897, measured in 1906 about 600 feet from east to west by 100 feet across and from 75 to 100 feet deep. (See Pl. XXXIV, *A*.) On the south side the stripping of drift increases from 5 feet in thickness at the west wall to 35 feet at the east wall, owing to the inclination of the rock surface.

Rock structure: The sheets, 1 to 8 feet thick, dip generally 5° S. There is but one set of joints, which strike N. 25° E., dip 70° W., spaced 5 to 50 feet. The rift is reported as horizontal, but feeble. A flow structure, shown by streaks of black mica, strikes N. 15° W. and dips west. There is a dike of aplite striking N. 25° E., dipping 70° W. The structural relations are shown in figure 93 and Plate XXXIV, *A*.

Since the diagram of figure 93 was made the process of excavation is reported to have shown in 1909 a narrowing of the granite dike below, but it may widen again farther down.

The problem presented by the structure here is whether this belt of granite 75 feet thick is simply a dike of indefinite depth or a minor protuberance in the undulating surface of a wide granitic intrusion which became exposed by the erosion of the overlying gneiss where it was thinnest. The gneiss (specimen D, XXVIII, 11, a) is of a very dark gray shade and fine to medium texture, but with porphyritic feldspars from 0.5 to 1½ inches in diameter, consisting of a light pinkish-buff potash feldspar (microcline and orthoclase), rimmed with milk-white soda-lime feldspar (oligoclase-andesine). The groundmass consists of the same potash feldspar, smoky quartz, the same soda-lime feldspar, and biotite. The granite is crossed at irregular intervals by pinkish and pyritiferous "streaks," veinlets from 0.1 to 0.4 inch wide, with a central thread of epidote. Their course is parallel to the joints. In thin section the soda-lime feldspars of these veinlets are much kaolinized and micacized. Rusty stain along sheets is 1 to 6 inches thick. Some joint faces are coated with a thin film of calcite; others with epidote from the alteration of feldspar.

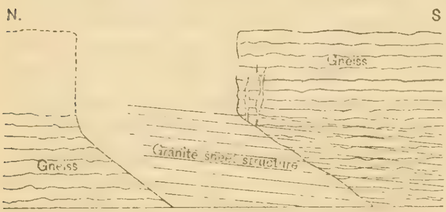

FIGURE 93. — Approximate structure at the Klondike quarry, in Charlestown, R. I. (See further on p. 415.)

Transportation, by cart 2½ miles to New York, New Haven & Hartford Railroad.

The product is used entirely for monuments.

The **Newall quarry** is in the town of Westerly just west of the Charlestown line, 5¼ miles about east of Westerly station, and 1¼ miles southeast of Bradford station. (See fig. 92.) Operator, Sullivan Granite Co., Westerly.

The granite (specimens D, XXVIII, 6, a, c), "blue Westerly," is a quartz monzonite of medium bluish-gray color, with very fine black particles. Its texture is even grained, fine, with feldspars and mica up to 0.1 inch. Its constituents, in descending order of abundance, are clear to milk-white striated soda-lime feldspar (oligoclase), somewhat kaolinized and micacized; pale smoky quartz, with few hairlike crystals, probably of rutile, and cavities; clear bluish to translucent potash feldspar (orthoclase and microcline), intergrown with quartz and slightly kaolinized; and biotite (black mica), some of it chloritized. Accessory: Magnetite, pyrite, allanite, zircon, rutile. Secondary: Kaolin, a white mica, carbonate.

An estimate of the mineral percentages, obtained by applying the Rosiwal method to a camera lucida drawing of part of a thin section enlarged 40 diameters, yields the following results with a 2-inch mesh and a total linear length of 38 inches.

Estimated mineral percentages in "blue Westerly" granite from the Newall quarry, near Westerly, R. I.

Soda-lime feldspar (oligoclase)	36.32
Quartz	29.38
Potash feldspars (microcline 17.91, orthoclase 8.00)	25.91
Biotite (black mica)	6.27
Magnetite	.60
Pyrite	.10
Apatite	.95
Allanite	.47
	100.00

Much weight should not be attached to the figures for apatite and allanite, for the mesh could have been shifted to avoid intersecting these particles, but their sum can be safely regarded as standing for the more abundant accessory minerals next to magnetite and pyrite. The average diameter of all the particles obtained by the same measurements is 0.0087 inch.

W. T. Schaller, chemist, of this Survey, finds that it contains 0.15 per cent of CaO (lime) soluble in dilute acetic acid, which indicates a content of 0.26 per cent of $CaCO_3$ (calcium carbonate), the presence of which is also shown by the microscope and by a slight effervescence with muriatic-acid test.

This is a fine-grained monumental granite susceptible of high polish and fine carving. It is of the same texture as the stone of the Klondike quarry and a little finer than the blue of the New England and Smith quarries. Its shade is a trifle darker than that of the granite from the Klondike quarry. The polished face shows many minute particles of magnetite and a few of pyrite. There is a marked contrast between the hammered and polished faces.

The quarry, opened in 1883, measured in 1906 400 to 450 feet from east to west by 250 feet across and from 50 to 100 feet in depth.

Rock structure: The sheets, 1 to 9 feet thick, are horizontal at the east end, dip 10°–15° W. at the west end and 15° S. at the bottom. There are two sets of joints—(a), strike N. 25° E., dip 75° ESE., spaced 5 to 200 feet; (b), strike N. 45° W., vertical, exceptional. The rift is reported as dipping 20° about east, but in places west, and the grain as striking east and vertical. The granite occurs in a dikelike mass about 100 feet thick, dipping 45° S. and both underlain and overlain by "white horse," which here is a light pinkish-gray biotite gneiss consisting of light-pinkish potash feldspar (microcline) in elongated crystals, smoky quartz, clear to milk-white oligoclase, and biotite. The foliation of this gneiss appears to strike about east and to dip with the surface 45° S. A pegmatite border separates granite from gneiss. Minute brownish veins traverse the gneiss. Rusty stain is up to 14 inches thick on sheet surfaces, and ferruginous water exudes from between them 25 to 50 feet down the quarry.

Transportation, by cart 1¼ miles to New York, New Haven & Hartford Railroad at Niantic, and thence 4½ miles by rail to cutting shed at Westerly.

The product is used exclusively for monuments. Specimens: Sarcophagus monument to Senator Sherman, Mansfield, Ohio; obelisk to Gen. Lew Wallace, Crawfordsville, Ind.; W. L. Elkins and P. A. B. Widener mausoleums, Central Laurel Hill, Philadelphia; monument to J. D. Putnam erected by Fourteenth Wisconsin Regiment on the battle field of Shiloh; reproduction of the elaborate Celtic cross of St. Martin in the island of Iona, erected by Mrs. McNeil in Rosedale Cemetery, Los Angeles, Calif.; T. M. Newall monument at Westerly, which has a delicate bas-relief of an entire poppy plant and a butterfly (design copyrighted).

The **Crumb quarry** is in Westerly, 1 mile S. 32° E. of Bradford station, and 5 miles about east of Westerly station. (See fig. 92.) Operator, Sullivan Granite Co., Westerly.

The granite, "blue Westerly," is a quartz monzonite of medium bluish-gray color, with very fine black particles, and even-grained, fine texture, identical with that of the Newall quarry, described on page 416.

The quarry, opened in 1857, measured in 1906 about 400 feet from east to west by 125 feet across and 40 feet in depth.

Rock structure: The sheets, 6 inches to 8 feet thick, are undulating horizontal. There are two sets of joints—(a), strike N. 25° E., dip, 50°–70° WSW., spaced 10 to 150 feet, forms a heading across the center; (b), strike N. 60° E., vertical, ex-

ceptional and discontinuous. The rift is reported as horizontal, but with a "run" dipping low east, and the grain as vertical, east-west. The granite occurs in a dikelike mass, apparently continuous with that of the Newall quarry, about 850 feet east-southeast of it. It is about 100 feet thick and is underlain on the north by a gneiss, "white horse," with a foliation and surface dipping 20°–40° S. This gneiss (specimen D, XXVIII, 12, b) is a light pinkish-gray biotite gneiss identical with that of the Newall quarry (p. 417). The light-pinkish feldspars (orthoclase and microcline) are in elongated lenses from 0.2 to 0.3 inch wide. The biotite is fine and sparse. Although the schistosity of the stone may be great enough to impair its strength, its contrasts of color are very attractive. The granite is crossed by a 1-inch pegmatite dike dipping 45° E. Rusty stain is 10 to 15 inches thick along sheet surfaces. The faces of joints (a) are in places bright reddish and thinly coated with radiating pearly crystals of a silicate, stilbite (?).

Transportation, by cart 1¼ miles to railroad at Niantic.

The product is used for monuments, which are made mostly in Quincy, Mass. Specimens: Alexander Thompson and Oliver Hazard Cooper monuments, Swan Point Cemetery, Providence; Rhode Island monument, Andersonville, Ga.

ADAPTABILITY OF NEW ENGLAND GRANITES.

A cursory glance at the paragraphs on "Product" in the foregoing quarry descriptions will suffice to show the great variety of adaptations of New England granites. Some, by their many joints and in places "shake structure," together with their situation at tidewater, supply irregular blocks of all sizes at low cost for breakwater construction. Others, by their marked rift and grain, lend themselves to the manufacture of paving blocks. Still others, by their even gneissic texture, are equally well adapted for curbing, crossings, and sills. Then come the coarse thick-sheeted granites useful in the construction of massive edifices, bridges, and their approaches and anchorages or retaining walls. Here belong also those coarse granites occurring in such thick sheets and with such sparseness of joints as to furnish large monolithic columns. Besides all these are the numerous granites suitable for ordinary buildings and monuments and offering to the architect a great variety of color, tint, and shade—pinkish, greenish, pale lavender, buff, cream-colored, bluish grays, many shades of gray, besides white, almost as white as white marble, and black (Norwich) suitable for sooty atmospheres.

These granites also include a wide range of texture. (See Pls. XXX, *A*, and XXXI, *A*, showing two of the coarse-textured ones.) Some granites by the fineness of their texture are adapted to delicate sculpture. Statuary, flowers, and intricate conventional designs can be carved in granite. Others by the height of their polish, the size of their porphyritic crystals and the colors, tints, and shades of their feldspars, quartz, and mica are adapted to interior decoration. Some of the quartz monzonites and the so-called black granites are specially useful as inscribed tablets or dies on account of the contrast between their polished and cut surfaces.

Finally there are the rust-colored granites and aplites (Rockport and Hingham, Mass.), affording, when used in connection with normal granites, unique contrasts of color; also the aplite of Hingham, of unusual compressive strength, sought after for keystones.

It would be difficult to name a use for granite which can not be supplied by some of the quarries described in this bulletin, and as to colors the only ones lacking in New England are the deep purple and deep reddish, which must be sought in Wisconsin or Scotland or Norway. Some reddish granites occur also in Minnesota, Missouri, Texas, and Oklahoma.

Among the notable structures and public monuments built of New England granite are the Library of Congress, Union Station, Post Office (including interior polished columns), National Museum, and Freer Art Collection Building, Washington; Hall of Records, customhouse, post office, Bank of Commerce, Bankers Trust Co. Building, pedestal of Statue of Liberty, columns of Cathedral of St. John the Divine, New York; soldiers and sailors' memorial, Syracuse, N. Y.; Cook County courthouse, Alexander Hamilton memorial, Grant Park, Chicago; State capitol, Madison, Wis.; Northwestern Mutual Life Insurance Building, Milwaukee, Wis.; Museum of Fine Arts, Minneapolis, Minn.; McKinley national memorial (including sarcophagi), Canton, Ohio; Lincoln memorial, Hodgenville, Ky.; State capitol, Harrisburg, Pa.; national monument, Gettysburg, Pa.; Pilgrim monument, Provincetown, Mass.; Bunker Hill Monument, Charlestown, Mass.; soldiers and sailors' monument, Whitinsville, Mass.; State library and Connecticut River Bridge, Hartford, Conn.

ECONOMIC CLASSIFICATION OF NEW ENGLAND GRANITES.

The granites of New England in respect to their general uses may be divided into nine classes—(A) constructional, used for buildings, bridges, retaining walls, pedestals; (B) monumental, used for monuments, and requiring finer texture than those of class *a;* (C) sculptural, used for delicate carving and statues, also for monuments; (D) inscriptional, adapted to inscriptions legible at a distance; (E) polish, susceptible of high polish; (F) rusty-faced, for buildings requiring special contrasts of color; (G) curbing and trimming, adapted by their gneissic texture for curbing, trimming, and sills; (H) breakwater, easily quarried and situated at tidewater, and thus adapted to the construction of breakwaters; (I) paving, suitable by their rift and grain for the manufacture of paving blocks. As the waste of some constructional and monumental granites is also used for paving, any enumeration of paving-stone quarries would be misleading. The quarries on the Maine coast and on Cape Ann, Mass., are the chief producers of paving blocks.

In the first of the following tables all the granites described in this bulletin, except a few unimportant prospects and hopeless quarries, are classified in the nine classes named. The locality, quarry name, trade name, color or tint and shade, texture, and scientific name of each granite are given in separate columns, together with a page reference to the description of stone and quarry. The localities are given by States in alphabetic order, but in each State the order is that of the quarry descriptions. The table gives all the granites but not all the quarries in which they occur.

In order to facilitate the search for granite of a particular color or shade all the granites of classes *a*, *b*, *c*, and *f* have been classified according to their dominant colors and shades, without reference to their uses, in Table 2. The designations of color or tint and shade make 17 groups—1, white; 2, black; 3, gray with strong contrasts, white dominant; 4, black and white, strong contrasts, black dominant; 5, gray, porphyritic; 6, gray with weak contrasts, light, medium, dark; 7, gray, light, medium, dark, tinted bluish, greenish, buff; 8, lavender tinted; 9, reddish gray, light, medium, dark; 10, pinkish gray, light, medium, dark, bright; 11, pinkish to light gray or light buff-gray, with large black spots; 12, pinkish-reddish buff; 13, buff; 14, cream-colored; 15, greenish, pea or olive; 16, mottled; 17, rust-colored.

TABLE 1.—*Economic classification of New England granites.*

Class A. Constructional.

Locality.	Quarry name.	Trade name.	General color and shade.	Texture.	Scientific name.	Described on page—
CONNECTICUT.						
Greenwich	Ritch, etc	Greenwich black	Extremely dark bluish gray	Coarse, gneissic, porphyritic	Mica diorite gneiss	362
Bristol	Dunn	Bristol	Light to medium bluish gray	Fine, gneissic, banded	Quartz monzonite gneiss	365
Norfolk	Crissey	Norfolk	Medium slightly greenish gray.	Fine, obscurely gneissic	Biotite-muscovite granite gneiss.	370
Roxbury	Rockside	Roxbury	Medium bluish gray	Fine, very gneissic	Muscovite-biotite granite gneiss.	371
Torrington	Costello		Medium faintly buff-gray	do	do	373
Do	Michiel		Medium to dark bluish gray, much mica on foliation face.	Medium, very gneissic	do	374
Branford	Norcross	Branford red	Medium reddish gray	Generally medium to coarse but very variable, gneissic, in places pegmatitic.	Biotite granite gneiss, pegmatitic.	377
Do	Stony Creek	Stony Creek red	do	do	do	379
Do	Opie	Light pink	Medium pinkish gray	Medium	Biotite granite	380
Do	Hoadly Neck, West	Hoadly Neck, West	Medium to dark reddish gray	Coarse to very coarse, gneissic, banded, plicated, porphyritic.	do	381
Do	Hoadly Neck, East	Hoadly Neck, East	Medium reddish gray	Medium inclining to fine, gneissic.	do	381
Guilford	Leete Island	Leete Island	do	Medium, obscurely gneissic	Biotite granite gneiss	382
Lyme	Selden Neck		Medium inclining to dark reddish gray streaked with black.	Fine, gneissic with lenses and laminæ of black silicate.	Hornblende-biotite granite gneiss.	390
Stonington	Murray	Red Westerly	Medium reddish gray	Medium inclining to coarse granitic.	Biotite granite	393
MAINE.						
Pownal	Pownal	Pownal	Light gray	do	do	211
North Jay	Maine & New Hampshire Granite Corporation.	North Jay white	Very light gray	Fine	Biotite-muscovite granite	212
Bluehill	White		Medium gray, slightly bluish	Coarse	Biotite granite	214
Do	Chase		Medium to light gray	do	do	215
South Brooksville	Bucks Harbor	Bucks Harbor	Light buff, grayish	Coarse to medium	do	216
Do	do	do	Medium gray	Coarse	do	217
Dedham	Brown		Dark gray, with light gray feldspar crystals.	Very coarse, porphyritic	do	217
West Franklin	Bradbury		Dark purplish gray with some yellowish particles.	Very coarse, somewhat porphyritic.	do	221
Black Island	Upper	Black Island	Light pinkish gray	Medium to coarse	do	221

TABLE 1.—*Economic classification of New England granites*—Continued.

Class A. Constructional—Continued.

Locality.	Quarry name.	Trade name.	General color and shade.	Texture.	Scientific name.	Described on page—
MAINE—continued.						
Black Island	Redcliff	Redcliff medium	Medium pinkish gray	Medium to coarse	Biotite granite	221
Mount Desert	Hall or McMullen		Light buff, grayish	Coarse to medium	do	222
Do	Campbell & Macomber	Somes Sound pink	Light pinkish gray	Medium to coarse	do	223
Crotch Island	Ryan-Parker and Goss	Crotch Island	Lavender-tinted medium gray with white spots.	Coarse	do	224
Moose Island	Moose Island	do	do	do	do	229
Crotch Island	Sherwood Upper		Pinkish buff	do	do	227
Green Island	Latty		do	do	do	228
Deer Isle	Settlement		Medium gray, slight lavender tint, with cream-white spots.	do	do	229
Swans Island	Baird		Medium pinkish buff	Medium to coarse	do	232
Do	Toothachers Cove		Medium pinkish gray	Coarse	do	232
Hallowell	Stinchfield		Light gray	Fine, porphyritic	Biotite-muscovite granite	233
High Isle	High Isle	High Isle	Slightly pinkish medium gray	Medium to coarse	Biotite granite	236
Dix Island	Dix Island	Dix Island	Somewhat dark gray	do	do	238
Sprucehead Island	Sprucehead	Sprucehead	Black, white, and gray	do	Quartz monzonite	238
South Thomaston	Weskeag		Slightly bluish medium gray	do	Biotite-muscovite granite	239
Clark Island	Clark Island	Clark Island	Medium gray	Fine to medium	do	339
Vinalhaven	Sands		Pinkish buff, medium	Coarse	Biotite granite	243
Do	Palmer		do	do	do	244
Do	Black		do	do	do	245
Hurricane Island	Hurricane Isle		do	do	do	247
Waldoboro	Waldoboro	Waldoboro	Medium gray	Fine to medium	Muscovite-biotite granite	249
Fryeburg	Eagle gray	Eagle gray	do	Medium	do	252
Woodstock	Bryant Pond		Bluish white and black	do	Quartz diorite	253
Guilford	Queen City		Light gray	Medium to coarse	Biotite-muscovite granite	255
Do	Brawn		do	do	do	255
Hartland	Hartland		Bluish white and black	do	Quartz diorite	255
Norridgewock	Lawton		Medium and also light gray	Medium, porphyritic	Quartz monzonite	256
Frankfort	Mount Waldo	Mount Waldo	Medium gray	Fine	Biotite granite	258
Calais	Several	Red Beach	Bright pinkish	Medium	do	266
Jonesboro	Fish		Lavender-tinted, medium gray, with white spots.	do	do	267
Do	Bodwell	Jonesboro red	Medium pinkish gray	Coarse to medium	do	267
Do	Booth Bros	do	do	do	do	269
Jonesport	Hardwood Island	Moose-a-bec red	Dark reddish gray with white spots.	Coarse	do	270
Marshfield	Marshfield		Medium pinkish gray	Medium to fine	do	271
Millbridge	Millbridge		Buff, medium	Medium	do	272
Biddeford	Gowan Emmons		Light gray	Coarse	do	274

Do	Wormwood		Medium pinkish buff	do	do	274
Do	Andrews		Light gray with black spots	do	do	275
Kennebunkport	Day		Medium gray with black spots.	do	Biotite-muscovite granite	276
Wells	Lord		Light pinkish gray with sparse black spots.	Medium to coarse	Biotite granite	277
MASSACHUSETTS.						
Fall River	Beattie	Fall River pink	Medium or light pinkish gray with black spots.	Coarse or coarse to medium gneissoid.	Biotite granite gneiss	282
Do	Beattie and Savoie	Fall River gray	Light buff gray or light gray with black spots.	Medium to coarse gneissoid	do	283, 284
New Bedford	New Bedford	Sullivan quarries	Light pinkish gray	Coarse to medium, slightly gneissoid.	Biotite-muscovite granite gneiss.	286
Dartmouth	Dartmouth		Very light buff-gray	Medium to coarse	Biotite-muscovite slightly gneissoid.	286
Peabody	Den	Peabody green	Dark or very dark olive-greenish.	Coarse	Hornblende-augite granite	288
Lynnfield	Robin Rock	Robin Rock green	Very dark greenish	do	do	289
Rockport	Flat Ledge, Deep Pit, etc.	Rockport gray, Bay View gray.	Medium gray	Medium to coarse	Hornblende granite	294, 301
Do	Blood Ledge, Cheves	Rockport sea-green	Dark olive	do	do	300
Monson	Flynt	Monson	Dark or very dark gray	Fine to very fine elongated (not plicated) gneissic.	Quartz-mica diorite gneiss	304
Pelham	Ward	Pelham	Dark bluish gray	Very fine, elongated (not plicated) gneissic.	Biotite granite gneiss	305
Acton	Harris	Acton	Light bluish gray	Fine gneissic	Biotite-muscovite-quartz monzonite gneiss.	307
Groton	Shaker	Groton	Medium bluish gray	Medium to fine, slightly porphyritic gneissic.	Muscovite-biotite granite gneiss.	308
Westford	Oak Hill	Oak Hill	Very light or very light, slightly bluish gray.	Medium, slightly porphyritic gneissic.	do	309
Do	Snake Meadow Hill	Graniteville	Very light or medium gray	Medium to fine, slightly porphyritic gneissic.	Muscovite-biotite quartz monzonite gneiss.	311
West Townsend	Barker Hill	West Townsend white	Light, faintly buff-gray	Medium to fine	Biotite-quartz monzonite	313
Wrentham	Curry	Wrentham	Light gray	Medium to coarse	Hornblende granite	314
Quincy	Winquist	Quincy extra light	Light pea greenish	Medium to coarse	Riebeckite aegirite granite	324
Milford	Milford	Milford pink	Light gray to medium pinkish, or pinkish-greenish gray, with black spots.	Medium to coarse, slightly gneissoid.	Biotite granite	344
Uxbridge	Blanchard	Uxbridge	Light to medium gray	Medium porphyritic, elongated gneissic.	Biotite granite gneiss	352
Fitchburg	McCauliff	Fitchburg	Light to medium bluish gray	Medium gneissic	Muscovite-biotite granite gneiss.	354
NEW HAMPSHIRE.						
Conway	Redstone	Conway pink	Light pinkish, mottled with dark gray.	Coarse	Biotite granite	166
Do	Redstone green	Redstone green	Dark olive-greenish	do	Biotite-hornblende granite	168
Do	White Mountain		Medium pinkish buff-gray	do	Biotite grainite	169
Madison	Fletcher		Light pinkish gray mottled with dark purplish gray.	do	do	170

TABLE 1.—*Economic classification of New England granites*—Continued.

Class A. Constructional—Continued.

Locality.	Quarry name.	Trade name.	General color and shade.	Texture.	Scientific name.	Described on page—
NEW HAMPSHIRE—contd.						
Fitzwilliam	Snow Flake	Snow Flake	Light to medium gray	Porphyritic with fine matrix	Biotite-muscovite granite	173
Do	Thompson		Medium gray	Fine	Muscovite-biotite granite	174
Marlboro	Webb-Marlboro	Marlboro	Light to medium, very bluish gray.	do	Biotite-muscovite granite	174
Troy	Troy	Troy white	Light to medium bluish gray	do	Muscovite-biotite granite	175
Kilkenny	Kilkenny	Kilkenny	Dark olive-greenish	Medium	Augite-biotite granite	176
Stark	Dawson	Stark	Medium pinkish gray	do	Biotite granite	177
Canaan	Mascoma	Mascoma	Light buff-gray with large black spots.	Gnessioid, coarse	Biotite granite gneiss	177
Lebanon	Lebanon	Lebanon pink	Light, faintly pinkish-greenish gray with large black spots.	do	Epidotic biotite granite gneiss	178
Milford	Lovejoy	Milford, N. H	Light gray	Fine to medium	Quartz monzonite	183
Do	Pease	do	Light buff-gray, some slightly pinkish.	do	do	184
Do	Carlton	do	Medium pinkish gray	Fine porphyritic	Quartz monzonite, probably.	189
Concord	Various	Concord	Medium bluish gray	Fine medium, somewhat porphyritic.	Muscovite-biotite granite	197–201
RHODE ISLAND.						
Westerly	Redstone	Red Westerly	Medium reddish gray	Medium to coarse	Biotite granite	412
VERMONT.						
Newark	Packer	Newark pink	Light pinkish gray	Coarse	Biotite granite	112
Randolph	Beedle prospect	Fine white	Extremely light gray	Fine	Quartz monzonite	118
Derby	Lacasse	Derby gray	Light bluish gray	Medium to fine	do	119
Barre	Millstone	Coarse light Barre	Light gray	Medium	Biotite granite	137
Woodbury	Fletcher & Woodbury	Woodbury gray	Light to medium gray	do	do	148, 149
Do	Vermont white	Vermont white	Very light cream-colored with black dots.	Medium to coarse	do	151
Dummerston	Black Mountain	Dummerston white	Very light gray	Medium	Quartz monzonite	153
Do	Bailey		Light gray	Medium to fine	do	155
Bethel	Woodbury & Ellis	Bethel white	Slightly bluish milk-white with grayish spots.	Coarse to medium	do	158
Rochester	Liberty Hill		Slightly greenish white, large micas.	Coarse	do	159
Plymouth	Morrison Hill	Plymouth white	Milk-white with rare disks of mica.	Fine	do	160

Class B. Monumental.

CONNECTICUT.						
Thomaston	Plymouth		Medium bluish gray	Fine	Quartz monzonite	372
Groton	Salter	Groton	Medium slightly greenish gray.	Fine (particles average 0.0235 inch).	do	385
Do	Eckerlein	Center Groton	Medium to dark greenish gray.	Fine (particles average 0.0256 inch).	do	386
Do	Kopp		Medium faintly greenish gray	Fine to very fine	do	387
Do	McGaughey	Mystic	Medium to dark faintly greenish gray.	Fine	do	387
East Lyne	Malnati & Carlson	Golden pink	Medium pinkish gray	do	do	388, 389
Old Lyne	MacCurdy		Medium pinkish-reddish gray with black spots.	Very coarse, porphyritic	Biotitic pegmatite	390
Stonington	New Anguilla	New Anguilla	Medium slightly bluish gray.	Fine	Quartz monzonite	392
Waterford	Millstone	Millstone	Medium dark gray, smoke-colored.	Fine (particles average 0.0354 inch).	do	394
Do	Waterford	Connecticut white	Medium buff-gray	Fine (particles average 0.0206 inch).	do	397
MAINE.						
Freeport	Freeport		Medium slightly bluish gray.	Very fine	Biotite-muscovite granite	211
Bluehill	Chase		Medium bluish gray	Fine, porphyritic	do	215
Crotch Island	Sherwood Lower	Sherwood monumental	Light, slightly buff-gray	Very fine	do	227
West Sullivan	Stimson		Medium gray	Fine to medium	Biotite granite	230
Hallowell	Stinchfield		Light gray	Fine, porphyritic	Biotite-muscovite granite	233
St. George	McConchie	Crown black	Very dark gray	Fine to medium	Norite	240
Do	Long Cove	Long Cove	Bluish medium gray	do	Biotite-muscovite granite	240
Bristol	Round Pond	Round Pond	Very dark and medium gray	Fine	Quartz diorite	248
Whitefield	Jewett		Very dark bluish gray	Fine to medium	do	251
Norridgewock	Taylor		Light gray	Very fine	Biotite-muscovite granite	257
Lincoln	Lincolnville	Lincolnville	Light gray	Fine to medium	Muscovite-biotite granite	260
Searsport	Bog Hill		do	Medium, porphyritic	Biotite granite	261
Swanville	Oak Hill	Oak Hill	Dark, slightly bluish gray	Fine	do	261
Calais	Gardner prospect		Very dark gray	do	Quartz diorite	264
Do	Beaver Lake		Black mottled with white and gray.	Coarse to medium, porphyritic.	Mica-quartz diorite	265
Do	Shattuck Mountain	Shattuck Mountain	Dark reddish-greenish gray	Medium to coarse	Biotite granite	265
Do	Mingo Bailey		Dark reddish, speckled with pale greenish.	Medium	do	266
Do	Maine Red Granite Co.		Bright pinkish	do	do	266
Biddeford	Ricker		Light gray, but with strong contrasts.	Coarse	do	274
MASSACHUSETTS.						
Becket	Hudson & Chester	Chester dark and light.	Medium bluish and dark bluish gray.	Fine, with trace of gneissic texture.	Muscovite-biotite granite	279
Otis	Newhall		Medium gray	Fine inclining to medium	Biotite-muscovite granite	282
Acton	McCarthy	Acton, fine	Medium bluish gray	Fine to very fine obscurely gneissic.	Quartz monzonite gneiss	307

TABLE 1.—*Economic classification of New England granites*—Continued.

Class B. Monumental—Continued.

Locality.	Quarry name.	Trade name.	General color and shade.	Texture.	Scientific name.	Described on page—
MASSACHUSETTS—contd.						
Townsend	Barker Hill	West Townsend white.	Light, faintly buff-gray	Medium inclining to fine	Quartz monzonite	313
Do	do	West Townsend red	Lght to medium pinkish gray.	do	do	313
Stoughton	Messer	Stoughton	Medium shade mottled color.	Coarse	Biotite or hornblende granite.	315
Cohasset	Tiffany	Cohasset	do	do	do	315
Quincy	Many	Quincy dark, medium, extra dark.	Dark gray (or bluish, greenish, purplish) to very dark bluish or purplish gray.	Medium to coarse	Riebeckite-aegirite granite	321-331
Do	Gold-leaf	Gold-leaf	Medium bluish-green gray with yellow-brown and black specks.	do	do	332
Braintree	Stacy	Red Braintree	Dull medium reddish gray	Coarse	Riebeckite-aegirite granite altered.	335
Leominster	Leavitt	Leominster	Dark to very dark bluish gray.	Very fine	Mica diorite	353
NEW HAMPSHIRE.						
Fitzwilliam	Victoria White	Victoria white	Light bluish gray	Very fine (average diameter, 0.0066 inch).	Biotite-muscovite granite	172
Troy	Troy	Troy white	Light to medium bluish gray.	Fine	Muscovite-biotite granite	175
Haverhill	Pond Ledge	Pond Ledge gray	Light to medium gray	Fine, but with sparse porphyritic feldspars.	Biotite-muscovite granite	179
Do	do	Pond Ledge pink	Light pinkish gray	do	do	179
Milford	Young	Dark blue New Westerly.	Dark gray (smoke color)	Fine (average diameter, 0.0084 inch).	Quartz monzonite	190
Do	New Westerly	New Westerly blue	Medium, slightly bluish gray.	Fine (average diameter, 0.009 inch).	do	188
Do	Tonella	Milford (N. H.)	Light to medium buff-gray	Fine (average diameter, 0.011 inch).	do	186
Do	Souhegan	Souhegan	Dark gray with very slight pinkish tinge.	Fine	do	187
Brookline	O'Rourke	Brookline	Medium buff-gray	do	do	191
Do	Fessenden	do	Medium, faintly pinkish gray.	Fine (average diameter, 0.0097 inch).	do	192
Auburn	Auburn	Deep-pink Auburn	Medium pink-buff	Fine	do	202
Sunapee	Perry Sunapee	Light Sunapee	Light, slightly bluish gray	Very fine to fine	Biotite-muscovite granite	204
RHODE ISLAND.						
Westerly	New England & Smith	Blue Westerly	Bluish medium gray	Fine (0.0099 inch)	Quartz monzonite	408,410
Do	do	Pink Westerly	Pinkish or buff medium gray.	Very fine (0.0069 inch)	do	408,410
Charlestown	Klondike	Blue-white Westerly	Bluish medium gray	Fine	do	415

VERMONT.						
Hardwick	Buffalo Hill	Dark-blue Hardwick	Dark gray	Medium porphyritic	Quartz monzonite	109
Kirby	Grout		Light to medium, slightly bluish gray.	Medium-fine	Biotite granite	110
Do	Burke		Light to medium gray	do	Quartz monzonite	111
Ryegate	Gibson, etc	Ryegate	do	Medium	do	114
Do	Rosa	Fine gray	Medium gray	Fine-medium	Biotite granite	116
Do	do	Coarse gray	Medium bluish gray	Medium	do	116
Groton	Benzie	Vermont blue	Medium quite bluish gray	Medium-fine	Quartz monzonite	116
Derby	Lacasse	Derby gray	Light bluish gray	do	do	119
Barton	Barnard	Barton	Medium gray	Medium	Biotite granite	121
Barre	Bruce, etc	Dark Barre	Dark to medium bluish gray.	Fine to medium	do	131
Do	Duffee, etc	Medium Barre	Medium bluish gray	do	do	136
Do	Jones Light, etc	Light Barre	Light to medium bluish gray.	do	do	133
Cabot	Lambert prospect	Dark gray	Dark bluish gray	Fine	Quartz monzonite	143
Calais	Patch	Medium gray	Medium, slightly bluish gray.	Medium	Biotite granite	144
Woodbury	Fletcher & Woodbury Granite Co.	Woodbury gray	Light to medium gray	Medium	Biotite granite	148, 149
Do	Bashaw	Woodbury Bashaw	Medium bluish gray	Fine to medium	do	149
Do	Imperial blue	Imperial blue	Dark bluish gray	Fine to medium, porphyritic.	do	151
Do	Nicols Ledge, Carter		Light to medium buish gray.	Fine to very fine	do	152

Class C. Sculptural.

CONNECTICUT.						
Groton	Salter	Groton	Medium, slightly greenish gray.	Fine	Quartz monzonite	385
Waterford	Waterford	Connecticut white	Medium buff-gray	do	do	397
MAINE.						
Hallowell	Stinchfield	Hallowell	Light gray	Fine, porphyritic	Biotite-muscovite granite	233
NEW HAMPSHIRE.						
Fitzwilliam	Victoria white	Victoria white	Light bluish gray	Very fine	do	172
Troy	Troy	Troy white	Light to medium bluish gray.	Fine	do	175
Milford	New Westerly	New Westerly blue	Medium, slightly bluish gray.	do	Quartz monzonite	188
Do	Tonella	Milford (N. H.)	Light to medium buff-gray.	do	do	186
RHODE ISLAND.						
Westerly	New England & Smith, etc.	Blue Westerly	Bluish medium gray	do	do	408, 410
Do	do	Pink Westerly	Pinkish or buff medium gray.	Very fine	do	408, 410
VERMONT.						
Barre	Jones light, etc	Light Barre	Light to medium bluish gray.	Fine to medium	Biotite granite	133
Woodbury	Bashaw	Woodbury Bashaw	Medium bluish gray	do	do	149

TABLE 1.—*Economic classification of New England granites*—Continued.

Class D. Inscriptional.

[Colors of polished face darker.]

Locality.	Quarry name.	Trade name.	General color and shade.	Texture.	Scientific name.	Described on page—
CONNECTICUT.						
East Lyme	Malnati & Carlson	Golden pink	Medium pinkish gray	Fine	Quartz monzonite	388, 389
Waterford	Millstone	Millstone	Medium dark gray, smoke-colored.	do	do	394
Do	Waterford	Connecticut white	Medium buff-gray	do	do	397
MAINE.						
West Franklin	Bianchi	Emerald granite	Very dark greenish gray	Medium, ophitic	Saussuritized grabbro	221
Vinalhaven	Bodwell "black granite" openings.	"Black granite"	Almost black	Fine, ophitic	Olivine norite	246
Hermon	Hermon Hill	do	Dark-green, with black crystals.	Ophitic, porphyritic	Altered diabase porphyry	254
Lincoln	Heal	do	Almost black	Ophitic	Olivine norite	260
Addison	Pleasant River	do	do	Medium, ophitic	Hypersthene-olivine gabbro	262
Baileyville	Hall	do	Very dark gray	Coarse, ophitic	Norite	263
Calais	Mingo Bailey	do	Almost black, slightly greenish.	Fine to medium, ophitic	do	264
Berwick	Miniutti	do	Very dark olive-greenish	Medium, ophitic	Gabbro	273
NEW HAMPSHIRE.						
Sunapee	Perry Sunapee	Dark Sunapee	Very dark bluish gray	Fine to medium	Quartz diorite	204
Millford	Souhegan	Souhegan	Dark gray	Fine	Quartz monzonite	187
RHODE ISLAND.						
Westerly	New England & Smith, etc.	Pink Westerly	Pinkish to buff medium gray.	Very fine	do	408
VERMONT.						
West Windsor	Mower	Ascutney green	Dark olive-green	Medium to coarse	Hornblende-augite granite	163
Windsor	Norcross	Windsor	do	do	do	163

Class E. Polish.

MAINE.						
Crotch Island	Ryan-Parker & Goss	Crotch Island	Lavender-tinted medium gray with white spots.	Coarse	Biotite granite	224, 226
Moose Island	Moose Island	do	do	do	do	229
Jonesport	Hardwood Island	Moose-a-bee Red	Dark reddish gray with white spots.	do	do	270
MASSACHUSETTS.						
Peabody	Linehan & Den	Peabody green	Dark to very dark olive-greenish gray.	Coarse	Hornblende-augite granite	287, 288
Rockport	Flat Ledge, etc	Rockport light gray	Medium gray	Medium to coarse	Hornblende granite	294
Do	Blood Ledge, etc	Rockport sea green	Olive-green	do	do	300
Do	Bay View prospect		Dark brownish gray	do	Riebeckite-aegirite-biotite granite.	302
Do	Pigeon Cove porphyry	Rockport porphyry	Very dark green with large medium gray crystals.	Fine, porphyritic	Diabase porphyry	303
Cohasset	Tiffany	Cohasset	Medium shade, mottled color.	do	Biotite or hornblende granite.	315
Quincy	Several	Quincy, dark, medium, extra dark.	Dark gray (or bluish, greenish, purplish) to very dark bluish or purplish gray.	Medium to coarse	Riebeckite-aegirite granite	321
Do	Gold-leaf	Gold-leaf	Medium bluish gray with yellow-brown spots.	do	Riebeckite-aegirite granite with granulated quartz and limonite.	332
NEW HAMPSHIRE.						
Conway	Redstone	Conway pink	Light pink mottled with dark gray.	Coarse	Biotite granite	166
Do	do	Redstone green	Dark yellow-greenish gray	do	do	168
Madison	Fletcher		Light pinkish gray mottled with dark purplish gray.	do	do	170
VERMONT.						
West Windsor	Mower	Ascutney green	Dark olive-green	Medium to coarse	Hornblende-augite granite	163
Windsor	Norcross	Windsor	do	do		163

Class F. Rusty-faced.

MASSACHUSETTS.						
Rockport	Flat Ledge	Sap faced	Bright rust color		Hornblende granite with much limonitic stain.	294
Hingham	Hingham, Miller & Hamilton.	Hingham, or Weymouth seam faced.	Rust color		Aplite with limonitic stain along joint faces.	336–339

TABLE 1.—*Economic classification of New England granites*—Continued.

Class G. Curbing and trimming.

Locality.	Quarry name.	Trade name.	General color and shade.	Texture.	Scientific name.	Described on page—
CONNECTICUT.						
Bridgeport	Burlison		Medium bluish gray	Fine, gneissic	Muscovite-biotite granite gneiss.	361
Glastonbury	Corbin and Brooks		Medium gray	Fine, gneissic, porphyritic	Biotite granite gneiss	366,368
Do	Glastonbury Granite Works.		Medium to dark gray	do	do	367
Do	Danielson		Dark to medium brownish gray.	do	do	368
Do	Belden		Medium buff-gray	Fine gneissic	do	368
Cornwall	Benedict		Medium bluish gray	Medium to fine gneissic	Biotite-muscovite granite gneiss.	369
Litchfield	Mascetti		Medium to light bluish gray	Fine gneissic	Muscovite-biotite granite gneiss.	370
Torrington	Costello		Medium, faintly buff-gray	Fine very gneissic	do	373
Do	Michiel		Medium to dark bluish gray.	Medium very gneissic	do	374
Ansonia	Potter		Medium bluish gray mica spangled on foliation face.	Fine gneissic	do	376
Seymour	Holbrook		Medium, marked bluish, gray spangled as above.	Fine, slightly plicated gneissic.	do	384
Waterford	Scott		Medium pinkish-purplish gray.	Very fine, slightly gneissic	Aegirite granite gneiss	394
Bolton	Peterson		Medium, slightly bluish gray with broad black streaks.	Medium very gneissic, porphyritic.	Biotite granite gneiss	399
Sterling	Marriott	Oneco	Medium to dark bluish gray.	Fine gneissic	do	400
Sterling	Bennett		Light pinkish gray with black streaks on foliation face.	Obscurely plicated, gneissic, much elongated porphyritic.	Biotite granite gneiss	401
Windham	Larrabee		Interbanded medium and dark gray.	Fine, gneissic	do	402
MAINE.						
Franklin	Robertson, etc		Medium gray	Coarse to medium	Biotite granite	218
East Franklin	T. M. Blaisdell		Medium to dark gray	Medium	do	219
Sullivan	Crabtree and Havey, etc		Medium gray	Fine to medium	do	230
Vinalhaven	Indian Creek		Light gray	Medium	do	246
Oxford	Roy		Medium cream-gray	Medium to coarse	Muscovite-biotite granite	253
Alfred	Bennett		Slightly greenish dark gray with black spots.	Medium	Quartz diorite	272

MASSACHUSETTS.						
Dartmouth	Dartmouth	Dartmouth	Very light buff-gray	Medium to coarse, slightly gneissoid.	Biotite-muscovite granite	286
Peabody	Linehan, etc	Peabody green	Very dark olive-greenish gray.	Coarse	Hornblende-augite granite	287
Lynnfield	Robin Rock	Robin Rock	Very dark greenish gray, also dark gray.	do	do	289
Monson	Flynt	Monson	Light to medium gray with fine bands of dark.	Fine to very fine, gneissic	Quartz-mica diorite gneiss	304
Westford	Merrill, etc	Oak Hill	Very light gray	Medium, gneissic, porphyritic.	Muscovite-biotite granite gneiss.	310
Do	Palmer, etc	Graniteville	Medium gray	Medium to fine, gneissic, porphyritic.	Quartz monzonite, gneiss	312
Fitchburg	Litchfield, etc		Light to medium bluish gray	Medium, gneissic	Muscovite-biotite granite gneiss.	354
NEW HAMPSHIRE.						
Stark	Dawson	Stark	Medium pinkish gray	Medium	Biotite granite	177
Milford	Kiltredge	Milford, N. H	Light gray, slight bluish tinge.	Fine to medium	Quartz monzonite	184
Nashua	Stevens		Light gray	Medium, gneissic	Muscovite-biotite granite gneiss.	193
Allenstown	Bailey	Allenstown	do	Medium	Muscovite-biotite granite	193
Hooksett	Shirley		Very light gray	do	do	194
Manchester	Kennard Ledge		Medium buff-gray	do	Biotite granite	195
Rochester	Langmaid		Very light gray	do	do	202

Class H. Breakwater.

CONNECTICUT.						
Guilford	Sachem Head		Medium reddish gray	Medium to fine, variably gneissose.	Biotite granite gneiss	383
Stonington	Masons Island		Banded light and dark gray.	Fine, gneissose, banded	Quartz monzonite flow gneiss	392
MASSACHUSETTS.						
Rockport	Folly Point Breakwater.		Gray	Medium to coarse	Hornblende granite	299

TABLE 1.—*Economic classification of New England granites*—Continued.

Class I. Paving.

Locality.	Quarry name.	Trade name.	General shade and color.	Texture.	Scientific name.	Described on page—
CONNECTICUT.						
Sterling	Bennett		Light pinkish gray with black streaks on foliation face.	Much elongated gneissose, porphyritic.	Biotite granite gneiss	401
MAINE.						
Mount Desert	Snowflake	Snowflake	Medium gray	Fine, porphyritic	Biotite granite	223
St. George	Willards Point		Bluish medium gray	Fine to medium	Biotite-muscovite granite	241
Vinalhaven	Pequoit		Medium gray	Fine, porphyritic	Biotite-hornblende granite	245
Do	Duschane Hill		Medium buff-gray	Fine to medium, porphyritic	Biotite granite	246
Do	Indian Creek		Light gray	Medium	do	246
Do	Armbrust		Pinkish buff, medium gray.	Coarse	do	246
MASSACHUSETTS.						
Rockport	Nickerson		Medium gray with slight buff tinge.	Medium to coarse	Hornblende granite	298

TABLE 2.—*The constructional, monumental, sculptural, and rusty-faced granites of New England grouped by dominant colors and shades.*

Group 1. White.

VERMONT.—Bethel, Plymouth, Randolph.

Group 2. Black.

CONNECTICUT.—Norwich.

Group 3. Gray with strong contrasts, white or gray dominant.

MAINE.—Biddeford: Ricker, Gowan Emmons, Andrews quarries. Kennebunkport: Day quarry. Bluehill: Chase quarry. South Thomaston: Weskeag quarry. Guilford: Queen City quarry. South Brooksville: Bucks Harbor quarries.

MASSACHUSETTS.—Wrentham: Curry quarry. Rockport: Devils Rock quarry.

VERMONT.—Derby: Lacasse quarry.

Group 4. Black and white, strong contrasts, black dominant.

MAINE.—Sprucehead Island: Sprucehead quarry. Hartland: Hartland quarry. Woodstock: Bryant Pond quarry.

Group 5. Gray, porphyritic.

MAINE.—Hallowell: Stinchfield quarry. Norridgewock: Lawton quarry. Frankfort: Mount Waldo. Searsport: Mount Ephraim (Bog Hill) quarry. Bluehill: Chase monumental quarry. Dedham: Brown quarry. West Franklin: Bradbury quarry.

MASSACHUSETTS.—Groton: Shaker quarry. Westford: Oak Hill and Snake Meadow Hill quarries. Uxbridge: Blanchard quarries.

NEW HAMPSHIRE.—Fitzwilliam: Snowflake quarry. Haverhill: Pond-ledge quarry.

VERMONT.—Hardwick: Buffalo Hill quarry. Woodbury: Drenan and Imperial Blue quarries.

Group 6. Gray with weak contrasts, light, medium, dark.

CONNECTICUT.—Waterford: Millstone quarry, medium and dark

MAINE.—Pownal: Pownal quarry, light. Jay: Maine & New Hampshire Granite Corporation quarry, very light. Sullivan: Stimson quarry, medium. Muscle Ridge Plantation: Dix Island quarry, dark. Bristol: Round Pond quarry, dark and medium. Waldoboro: Waldoboro quarry, medium. Norridgewock: Taylor quarry, light.

NEW HAMPSHIRE.—Milford: Tonella old quarry, light.

VERMONT.—Kirby: Burke quarry, light to medium. Ryegate: Rosa quarry, fine gray. Barton: Owen aplite prospect, dark.

Group 7. Gray, light, medium, dark (tinted bluish, greenish, buff).

CONNECTICUT.—Bristol: Dunn quarry, light to medium bluish. Norfolk: Crissey quarry, medium greenish. Roxbury: Rockside quarry, medium bluish. Torrington: Costello quarry, medium buff; Michiel quarry, medium to dark bluish. Thomaston: Plymouth quarry, medium bluish. Croton: Salter quarry, etc., medium greenish. Stonington: New Anguilla quarry, medium bluish. Waterford: Waterford quarry, medium buff.

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MAINE.—Freeport: Medium bluish. Bluehill: White quarry, medium bluish. South Brooksville: Bucks Harbor quarries, light buff. Mount Desert: Hall quarry, light buff. Crotch Island: Sherwood lower quarry, light buff. South Thomaston: Weskeag quarry, bluish medium. St. George: Long Cove quarry, bluish medium. Whitefield: Jewett quarry, very dark bluish. Swanville: Oak Hill quarry, dark bluish.

MASSACHUSETTS.—Becket: Hudson & Chester quarry, medium bluish. Dartmouth: Very light buff. Pelham: Dark bluish. Acton: McCarthy quarry, medium bluish. Townshend: Barker Hill, light buff. Quincy: Dark to very dark bluish, greenish or purplish. Leominster: Dark bluish.

NEW HAMPSHIRE.—Fitzwilliam: Victoria White quarry, light bluish. Marlboro: Light to medium bluish. Troy: Light to medium bluish. Concord: Various quarries, medium bluish. Milford: New Westerly quarry, medium bluish. Tonella: (King) quarry, medium buff. Brookline: O'Rourke quarry, medium buff. Sunapee: Perry quarry, light bluish.

RHODE ISLAND.—Westerly: Various quarries, medium bluish. Charlestown: Klondike quarry, medium bluish.

VERMONT.—Kirby: Grout quarry, light to medium bluish. Ryegate: Rosa quarry, (coarse) medium bluish. Groton: Benzie quarry, medium bluish. Derby: Lacasse quarry, light bluish. Barre: Various quarries, light, medium, dark bluish. Cabot: Bluish. Calais: Patch quarry, medium bluish. Woodbury: Bashaw, Imperial Blue, and Nicols Ledge Carter quarries, bluish, medium, dark, light to medium.

Group 8. Lavender-tinted.

MAINE.—Crotch Island: Ryan-Parker, Goss, and Benvenue quarries. Moose Island: Moose Island quarry. Jonesboro: Fish quarry.

Group 9, Reddish gray, light, medium, dark.

CONNECTICUT.—Branford: Norcross and Stony Creek quarries, medium. Hoadly Neck: Medium to dark. Guilford: Leete Island quarry, medium. Lyme: Selden Neck quarry, medium to dark. Stonington: Murray quarry, medium. Old Lyme: MacCurdy quarry, medium.

MASSACHUSETTS.—Braintree: Stacy quarry, medium.

RHODE ISLAND. Westerly: Redstone quarry, etc., medium.

Group 10. Pinkish gray, light, medium, dark, bright.

CONNECTICUT.—Brandford: Opie quarry, medium. East Lyme: Malnati & Carlson quarries, medium.

MAINE.—Black Island: Light and medium. Mount Desert: Campbell & Macomber quarry, light. Swans Island: Toothachers Cove quarry, medium. High Isle: Medium. Calais: Several quarries, bright. Jonesboro: Bodwell & Booth Bros. quarries, medium. Marshfield: Medium. Wells: Lord quarry, light.

MASSACHUSETTS.—New Bedford: Sullivan quarries, light. Townshend: Barker Hill quarry, light to medium.

NEW HAMPSHIRE.—Conway: Redstone quarry, light with large dark-gray and small black spots. Madison: Fletcher quarry, light, mottled with dark purplish gray. Milford: Carlton quarry, medium; Souhegan quarry, dark. Brookline: Fessenden quarry, faintly pinkish.

RHODE ISLAND.—Westerly: New England, Smith, and other quarries, medium.

VERMONT.—Newark: Packer quarry, light.

Group 11. Pinkish to light gray or light buff-gray with large black spots.

MASSACHUSETTS.—Milford: Various quarries. Fall River: Beattie, Savoie, and other quarries.
NEW HAMPSHIRE.—Canaan: Mascoma quarry. Lebanon: Lebanon quarry.

Group 12. Pinkish to reddish buff.

MAINE.—Crotch Island: Sherwood Upper quarry. Green Island (Stonington): Latty quarry. Swans Island: Baird quarry. Vinalhaven: Sands, Palmer, and Black quarries. Hurricane Island: Hurricane Island quarry. Biddeford: Wormwood quarry.

Group 13. Buff.

MAINE.—Millbridge: Millbridge quarry.

Group 14. Cream-colored.

VERMONT—Woodbury: Vermont White quarry, very light cream-colored.

Group 15. Greenish, pea, or olive tint.

MASSACHUSETTS.—Peabody: Den quarry, dark to very dark olive-greenish. Lynnfield; Robin Rock quarry, very dark greenish. Rockport: Bloodledge and Cheves quarries, dark olive-greenish. Quincy: Lepage, Winquist & Cashman quarries, light pea-greenish.
NEW HAMPSHIRE.—Conway: Redstone green quarry, dark olive-greenish. Kilkenny: Kilkenny quarry, dark olive-greenish.

Group 16. Mottled.

CONNECTICUT.—Lyme: Joshua Rock quarry, general purplish gray with fine reddish, pinkish, greenish, and black bands, also cherry-reddish spots.
MASSACHUSETTS.—Stoughton: Messer quarry, mottled pink, pea-green and medium gray. Cohasset: Tiffany quarry, mottled pink, pea-green, cream-color, medium gray, and black (very dark green).

Group 17. Rust-colored.

MASSACHUSETTS. Rockport: Flat Ledge quarry, bright rust color. Hingham: Hingham, Miller, and Hamilton quarries, rust color.

GEOLOGIC FACTORS IN GRANITE QUARRYING.

The problems confronting the granite quarryman about to open a quarry are many. Their solution requires not only practical experience in granite quarrying and soundness of judgment but also a little knowledge of geology and mathematics.

It is first of all assumed that suitable specimens representing the average quality of the fresh rock have been procured and subjected either by the United States Bureau of Standards or else by competent persons provided with the necessary machines and instruments to the tests enumerated on pages 99–103 in order that the quality of the stone may be determined apart from all commercial considerations.

The next step is a careful exploration of the granite surface, if necessary by stripping in trenches, to determine the areal extent of the stone of the quality tested, the spacing of the joints, the number and location of headings, dikes, veins, and the quantity of knots. A sufficient amount of vertical exploration should be done, if necessary by core drilling, to determine the thickness of the sheets, width of sap, course and quality of rift and grain, and also, if possible, the direction of the flow of the granite.

That the quarryman needs to have at least a rudimentary knowledge of geology is shown by the danger of his confounding, for want of it, igneous and sedimentary rocks. As granite issued from below, the supply of the granite of any given area is exhaustless in the direction of the source of its flow. A granite mass can never be penetrated in quarrying except in a direction transverse to that of its flowage. Quarrymen have been known to imagine that granite occurs in "pockets," like outliers of a sedimentary rock left by the erosion of the rest of the bed. This error arises from their having quarried across the flow of a granite dike instead of toward its source. But as the channel through which the granite flowed may narrow or widen it is well to determine by diamond drilling whether the narrowing is to prove great enough to enhance the cost of quarrying.

With these geologic preliminaries as to the area, quality, structure, and source of the granite disposed of, there remain the purely technologic problems as to the selection of quarry site, location of dumps, the drainage, water supply, transportation, the use of explosives, and method of splitting, and the machinery for hoisting, drilling, and transporting, none of which lie within the province of this bulletin.

THE PRODUCTION OF GRANITE IN THE NEW ENGLAND STATES.

By A. T. Coons.

HISTORICAL REVIEW.[81]

PERIOD BEFORE THE CIVIL WAR.

The stone industry in New England began in colonial times with the use of boulders and cobbles. The splitting of dimension stone from boulders was a crude operation. The stone for King's Chapel, built in 1749–1754 and considered an architectural masterpiece at the time, was obtained by dropping heavy iron balls upon heated boulders and hammering the split stone into shape. Split stone was used mainly in the construction of wharves, foundations, and wells, and cobbles were used for street paving. The sources of supply were

[81] Adapted from text by G. F. Loughlin, forming a chapter in the "History of the mineral industries," compiled by E. W. Parker for the Carnegie Institution.

within reasonable distance for transportation by water or by teams of oxen. About the beginning of the nineteenth century considerable granite was conveyed to Boston from Quincy, Mass., by ox teams and from Chelmsford (now Westford), Mass., by canal. Quarrying from the ledge began in Quincy in 1825 to supply stone for the Bunker Hill Monument, and with the introduction of quarry implements and the "plug and feathers" or "wedge and half-rounds" method of splitting stone, the industry developed rapidly.

The first quarries of more than local importance were convenient to water transportation, on the coasts of Massachusetts and Maine. The rapid growth of American commerce, with the resulting requirements for harbor improvements and coast protection, created a strong demand for granite in the construction of jetties, sea walls, wharves, and forts. This demand was supplied at first from quarries at Quincy and Cape Ann, Mass., and later from quarries in Rhode Island and Connecticut also. During the century that has elapsed since the opening of the first ledge quarry at Quincy other uses have been developed to so great an extent and the requirements for sea walls and similar construction work have been so well supplied that granite for such work now constitutes only a small part of the total output.

The use of granite for architectural work also grew rapidly during the second quarter of the nineteenth century, and many buildings in the larger cities on the Atlantic coast were erected of granite from the coast of New England. The Quincy granite, owing, no doubt, to its reputation gained as the stone used in Bunker Hill Monument, to its favorable position near tidewater, and to the more advanced methods of quarrying it, was probably the leading building granite during this period, although other granites along the coast of Maine and Massachusetts were finding an equally extensive range of markets. Inland granites of New England, now well known, were supplying mostly local demands, which included a few important buildings, such as the State capitols of New Hampshire and Vermont. Toward the middle of the century the construction of railroads, by furnishing transportation, began to give these granites more extensive markets.

Granite paving blocks were introduced into Boston in 1840, into Philadelphia in 1848, and into New York about 1850 and soon became one of the principal granite products. The blocks first used were considerably larger than the modern blocks, their surfaces measuring a square foot or more in area; but experience soon resulted in the adoption of blocks essentially like those used to-day.[82]

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[82] Brayley, A. W., History of the granite industry in New England, vol. 1, pp. 167–170, Boston, 1913.

Granite flagstones, principally from Quincy and Rockport, Mass., were probably introduced before the Civil War, and flagstones from granite quarries along the coast of Maine were probably used in Boston and other cities along the Atlantic coast not long afterward.

Granite was only occasionally used as a monumental stone until after 1860, but by 1880 its desirability for this use had become generally appreciated.

The available data on production of stone for the early years of the industry are very incomplete and represent only the leading quarries and possibly also the cutting plants. Much stone produced for local use and rough construction work, such as walls, piers, and docks, was probably not included in the figures of production. The report of the Eighth Census, for 1860, gives only the total value of all kinds of stone produced in the New England States. The value of the output of Connecticut ($532,704) was mostly for sandstone, and that of Massachusetts ($289,626) included granite, marble ($122,496), and "pudding stone." Granite produced in Maine in that year was valued at $295,280, in New Hampshire at $23,540, and in Rhode Island at $6,800, but none was reported from Vermont. The granite industry in Maine and Massachusetts was then considered very prosperous.

PERIOD SINCE THE CIVIL WAR.

BUILDING STONE.

There are no data available to show the effect of the Civil War upon the granite industry of New England, and none of much value to show the size and growth of the industry before 1880. The figures compiled by the Ninth Census,[83] for 1870, suggest a substantial increase in the total value of output of the leading quarries compared with the period before the Civil War, but the comparison is obscured by the fact that prices were relatively high in 1870. During the 25 or 30 years after the Civil War the granites that were the most prominent before the war still led in production. The darker-red granites of Maine, the dark bluish-gray granite of Quincy, Mass., and the lighter-gray granites of Rockport, Mass., Hallowell, Maine, and Concord, N. H., were prominent among building stones. The lighter-pink coarse-grained granites had been regarded with less favor by some because of their coarser texture and because their minerals lacked sufficient contrast in color, especially for monumental work.[84] Gradually, however, and probably owing in large part to the growing popularity of the buff and gray limestone from

[83] Ninth Census, vol. 3, p. 749, 1872.
[84] Merrill, G. P., Stones for building and decoration, p. 61, 1903.

Indiana, tastes changed in favor of the lighter-colored building stones, and from 1895 to 1900 the pale-pink granites, particularly those of the Penobscot Bay district, Maine, and Milford, Mass., became prominent. Some of the darker-colored granites found a growing demand as monumental stone.

From 1865 to 1890 the principal granite products were building, paving, and monumental stone. Crushed stone for water-bound macadam was gaining recognition, though its output was insignificant compared with that of to-day.

The general increase in the industry in 1889 as compared with 1880 is striking (see table, p. 443) but does not imply a steady growth. Sales of stone in general were thought to have decreased in 1883 owing to a marked preference for brick construction, and they decreased again in 1884 owing to a general industrial decline. In 1885, however, both the output of granite and its popularity for ornamental and decorative use showed a gain, whereas prices, owing to increasing competition, declined. From then until 1890 the industry was prosperous. This half decade was the first of two conspicuously prosperous periods for the building-stone industry since annual statistical information has been available.

This period of prosperity was followed by a decline in the demand for buildings and by the panic of 1903, when the output of structural stone and clay products decreased greatly. The output of stone as a whole continued to diminish until 1896, when the total value of all building stone sold was estimated at $10,000,000. The production of Portland cement was then beginning to increase rapidly, but the demand for buildings, after five years of curtailment, had now become so great that all structural materials found ready markets, and their production increased until 1902. After two years of decrease the sales of building stone as a whole increased until 1906, which marks the end of the second prosperous period of the industry. After a marked decline in 1907 and 1908 sales of granite for building fluctuated with a slight net gain until 1913, in spite of keen competition with lower-priced building materials for both rough construction and higher grades of architectural work. The effect of this competition has been gradual restriction of granite to the more costly buildings.

The drastic curtailment in high-class building during the war period 1914–1918 was to be expected, and since then the high costs of production and transportation together with labor troubles have delayed revival of the building-stone industry. There is, however, another shortage of buildings, and with industry in general becoming stabilized the demand for building granite may be expected to increase.

GRANITE FOR OTHER USES.

Monumental stone—As already stated, the use of granite for monumental stone had attained considerable prominence by 1880. Since then the production of monumental granite has made such districts as Barre, Vt., Quincy, Mass., and Westerly, R. I., famous throughout the country. The output was on the whole steady (see fig. 95, p. 442) until the war period, when the abnormal prosperity of some industries and the increased demand for memorials caused a marked increase, whereas the output of other granite products greatly decreased. The severe depression that followed the war, however, greatly reduced the demand for monumental stone, and curtailment of output has been continued by labor troubles, which have led producers of monumental granite in particular as well as several producers of granite of other classes to adopt what is practically the open shop.

Paving stone.—The demand for paving stone appears to have continued steadily except in periods of general depression until about 1895, when keen competition began with other materials that had certain advantages over granite blocks as then prepared and laid. The years 1909–1911 marked a high point in both the quantity and value of granite paving blocks sold from New England quarries, as well as from all quarries in the United States. This period was followed by a slight decline and by a second high point in 1913–14. The expected decline during the war period lasted until 1919, when, owing to renewal of street improvement in cities that had the heaviest traffic, the paving-block output began to increase. It declined again in 1920, but increased in 1921, when the value of the paving blocks sold was the largest ever recorded. There is no question regarding the greater resistance to wear of granite paving blocks as compared with competing materials, and the latest improved methods of preparing and laying them produce smooth road surfaces that will maintain their smoothness so long as the foundation upon which the blocks rest withstands the weight of traffic. As cheaper pavements are proving satisfactory for light to rather heavy traffic, the growth of the granite paving-block industry is expected to keep pace with that of extremely heavy city traffic.

Crushed stone.—The demand for crushed stone began late in the nineteenth century with the introduction of water-bound macadam roads. The use of crushed stone in concrete for foundations and buildings began about 1900, and its effect on the building-stone industry was soon noticeable. By 1907 the value of the crushed stone sold exceeded the combined values of the building and monumental stone. The quarries of the New England States were among the first to supply crushed stone, but most of this material was basalt. Few of the New England quarries that supply building and monumental

granite furnish crushed stone in any quantity. Massachusetts is the largest producer, and the greater part of the output comes from quarries especially operated and equipped for turning out this product. The production of crushed granite from the New England quarries, except for yearly fluctuations due to the effect of business conditions on the demand, showed a general moderate increase from 1896 to 1915, when the unusual conditions caused by the war brought about a rapid decline, and in 1918 the output was less than in any other year since 1902. A small increase in 1919 was followed by decreases in 1920 and 1921, but production in each of these years exceeded that of 1918. At present water-bound macadam is being superseded by asphaltic and cement-concrete pavements, in which gravel is used as well as crushed stone for the aggregate. Specially prepared crushed granite is finding considerable favor in terrazzo work for floors and in the better class of concrete exterior construction. In this work the color of the stone, as well as its durability, is of importance.

Conclusion.—The development of several products from one quarry and the finding of uses for what has heretofore been waste are indications of the present trend of the industry. The diversification of the granite industry and increased competition of all its products with other materials has resulted in gradual elimination of companies not properly equipped and financed to meet the present exacting requirements. The industry has advanced in the last century from one of primitive methods to one requiring elaborate and expensive equipment. A comparison of the years 1902 and 1919 in the census table (p. 443) shows that although the number of quarries and employees greatly decreased, the output did not change in proportion.

The production since 1896 is shown in the accompanying diagrams (figs. 94–96).

STATISTICS OF PRODUCTION.

The figures of production for the different States given in the accompanying tables are compiled from the records of the United States Geological Survey and for the years prior to 1882 from the reports of the Bureau of the Census. The Survey figures are totals of reports from the quarrymen. The values given are values f. o. b. at point of shipment and are based on the way the quarryman sells his stone. If the stone is cut by the producer, the value of the dressed stone is used. At Barre, Vt., and Quincy, Mass., most of the stone is sold in the rough by the producers to mills and manufacturing plants in the vicinity. The stone quarried at Rockport and Milford, Mass., Woodbury, Vt., Westerly, R. I., Stony Creek and Waterford,

Conn., North Jay, Maine, and Redstone, Concord, and Milford, N. H., is sold largely as dressed stone.

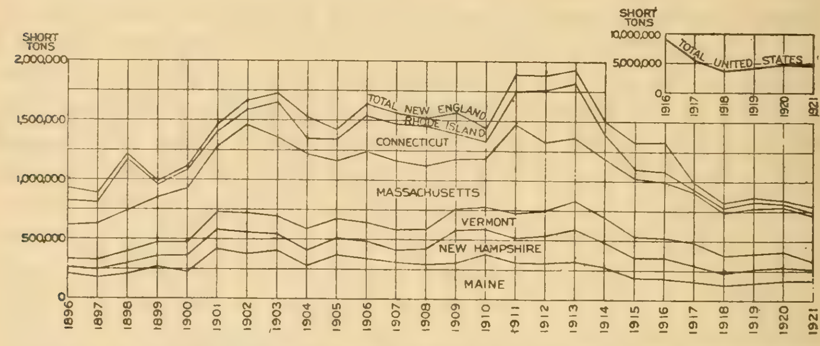

FIGURE 94.—Granite produced in New England, 1896–1921, and in the United States, 1916–1921.

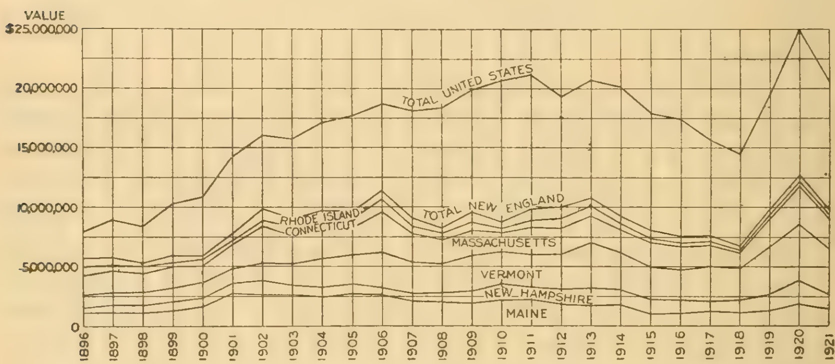

FIGURE 95.—Value of granite produced in New England and in the United States, 1896–1921.

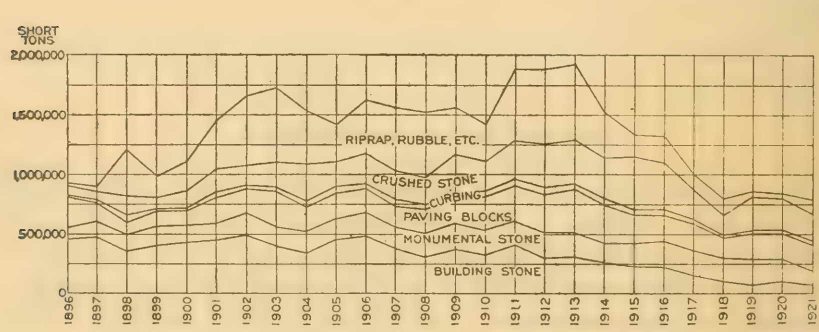

FIGURE 96.—Granite of different classes produced in New England, 1896–1921. The space between two adjacent curves shows the production of the class specified, and the upper curve indicates total production.

In preparing the diagrams (figs. 94–96) the available figures for quantity were used, and such estimates as were necessary were based on the knowledge that average values did not vary greatly for the different products between the years 1891 and 1916.

PRODUCTION BY CENSUS YEARS.

Approximate annual statistics of stone production began to be collected in 1880, but no separate figures of the different granite products were compiled until 1889. The following table, compiled from reports of the Bureau of the Census and the United States Geological Survey, reflects the condition of the granite industry in New England in the different census years:

Granite produced in the New England States in 1880, 1889, 1902, 1909, and 1919.

	1880	1889	1902	1909	1919
Maine:					
Number of quarries	68	153	110	85	44
Average number of wage earners	4,687	3,737	2,832	2,132	747
Acreage of quarry land	....	....	....	2,927	2,016
Production—					
Approximate quantity, short tons	183,000	563,000	378,000	300,000	149,820
Value	$1,175,286	$2,225,839	$2,659,450	$1,939,524	$1,274,474
New Hampshire:					
Number of quarries	39	78	51	40	24
Average number of wage earners	513	1,253	1,219	1,305	589
Acreage of quarry land	....	....	....	5,947	4,688
Production—					
Approximate quantity, short tons	159,400	240,000	178,000	270,000	104,690
Value	$303,066	$727,531	$1,147,097	$1,215,461	$1,443,205
Vermont:					
Number of quarries	12	53	74	53	29
Average number of wage earners	105	961	1,505	2,035	1,062
Acreage of quarry land	....	....	....	1,986	1,987
Production—					
Approximate quantity, short tons	16,000	90,000	167,000	186,000	133,627
Value	$59,675	$581,870	$1,570,423	$2,811,744	$4,031,735
Massachusetts:					
Number of quarries	92	151	[a] 115	82	45
Average number of wage earners	2,246	3,333	[a] 2,700	2,278	1,034
Acreage of quarry land	....	....	....	2,914	3,384
Production—					
Approximate quantity, short tons	388,000	805,000	742,000	415,000	383,760
Value	$1,329,315	$2,503,503	$3,080,857	$2,164,619	$2,477,938
Connecticut:					
Number of quarries	32	53	[a] 35	38	14
Average number of wage earners	872	1,630	[a] 800	868	92
Acreage of quarry land	....	....	....	1,149	410
Production—					
Approximate quantity, short tons	213,000	322,000	131,000	223,000	52,730
Value	$407,225	$1,061,202	$524,629	$610,514	$205,124
Rhode Island:					
Number of quarries	17	37	19	26	10
Average number of wage earners	760	1,195	638	675	262
Acreage of quarry land	....	....	....	500	433
Production—					
Approximate quantity, short tons	114,000	242,000	60,000	169,000	40,503
Value	$623,000	$931,216	$734,623	$933,053	$426,868
Total New England:					
Number of quarries	260	525	404	324	166
Average number of wage earners	9,183	12,109	9,694	9,293	3,786
Acreage of quarry land	....	....	....	15,423	12,918
Production—					
Approximate quantity, short tons	1,073,400	2,262,000	1,656,000	1,563,000	865,130
Value	$3,897,567	$8,031,161	$9,717,079	$9,674,915	$9,859,344

[a] The Bureau of the Census gives for Massachusetts 204 quarries and 3,395 wage earners and for Connecticut 49 quarries and 943 wage earners. These figures include basalt quarries, which are here deducted according to United States Geological Survey records. The number of wage earners is estimated.

PRODUCTION BY STATES.

MAINE.

The quarry industry in Maine was of considerable magnitude from about 1876 to 1911 but has decreased about 50 per cent in the last 10 years. The quarries started as a result of the usual local demand, but

their nearness to tidewater furnished a splendid outlet for the stone, and although New York and vicinity has been the largest market, it has been shipped to all the eastern coast cities and also by rail to Chicago, St. Louis, Atlanta, Albany, and many other interior cities. The chief use for Maine granite until recently has been for bridges, piers, buttresses, and all kinds of heavy masonry, as well as public buildings and residences. Paving blocks formerly ranked second in output, but in 1921 the amount of stone that was cut into paving block was more than twice as much as all the other stone quarried. In 1911 the the tonnage for paving blocks was about one-half as much as for the other products. About 3 per cent more blocks were produced in 1921 than in 1911, so that although the paving-block business in the State has held its own in competition with the different kinds of paving materials, the demand for all other constructional granite, including curbing and a negligible amount of monumental stone, has suffered keenly from the competition of stone from other States, but chiefly from the use of concrete for buildings and foundations.

The report of the Tenth Census (1880) shows that some of the quarries in operation at that time had been opened at the dates indicated below.

Cumberland County:
- Brunswick, 1836.
- Pownal, 1860–1872.

Franklin County:
- Chesterville, 1845.
- North Jay, 1872–1876.

Hancock County:
- West Sullivan, 1840–1876.
- Deer Isle, 1870–1877.
- Mount Desert, 1871.
- East Blue Hill, 1872–1879.
- Franklin, 1879.

Kennebec County:
- Hallowell, 1800.
- Augusta, 1856–1877.

Knox County:
- Spruce Head, 1836.
- Vinalhaven, 1850–1879.
- Dix Island, 1851.
- South Thomaston, 1859–1878.
- Hurricane Isle, 1870.
- St. George, 1874.

Lincoln County:
- Waldoboro, 1830.
- Round Pond, 1877.

Waldo County:
- Frankfort (Mount Waldo), 1853.
- Lincolnville, 1876.

York County, Biddeford, 1860–1868.

These dates show the beginning of the granite industry in the State, but until 1860 activity in the quarries was only local, and it was not until about 1870 that they became well known.

The granite quarries operated in Maine during 1921, as known to the United States Geological Survey, were as follows:

Granite quarries operated in Maine in 1921.

County.	Nearest town.	Operator.	Use of stone.
Cumberland	Westbrook	Jas. H. Pride	Foundations, monuments, and curbing.
Franklin	North Jay	Maine & New Hampshire Granite Co.	Buildings, monuments, mausoleums, paving blocks, curbing, riprap, and crushed stone.
Hancock	East Franklin	T. M. Blaisdell	Curbing, monument bases.
	Franklin	W. B. Blaisdell & Co.	Curbing, paving blocks.
	do	Bradbury, Blaisdell & Smith.	Monument bases.
	do	Bradbury & Orcutt	Do
	do	S. A. Bragdon (Darling Hill quarry).	Do.
	do	Bunker Bros.	Do.
	do	Jas. M. Clark	
	do	Gay & Springer	Do.
	do	Hutchins & Goodwin	Do.
	do	Arno Wooster	Curbing, paving blocks.
	Hall Quarry	Booth Bros. & Hurricane Isle Granite Co. (Somes Sound quarry).	Monuments, paving blocks.
	do	Mount Desert Granite Co.	Paving blocks.
	North Sullivan	R. F. Stanley	Monument bases.
	Stonington	John L. Goss Corporation	Buildings, monuments, mausoleums, riprap.
	do	Rodgers Granite Corporation.	Buildings.
	Sullivan	H. H. Havey & Co.	Monuments, paving blocks. curbing.
	do	H. E. Robertson	Paving blocks, curbing.
	West Sullivan	E. C. Gordon	Curbing, riprap.
	do	Webb & Staples Co.	Monument bases.
Kennebec	Hallowell	Hallowell Granite Works	Monuments, mausoleums, building, paving blocks, riprap.
Knox	Long Cove	Booth Bros. & Hurricane Isle Granite Co.	Monuments, paving blocks, durax blocks.
	Rockland	John Meehan & Son (Clark Island quarry).	Paving blocks.
	St. George	St. George Granite Co. (Williard's Point quarry).	Do.
	South Thomaston	Bassick Bros.	Monuments.
	Vinalhaven	J. Leopold & Co. (East Boston quarry).	Monuments, paving blocks, durax blocks.
	do	Roberts Harbor Granite Co. (Pequoit quarry).	Paving blocks.
Lincoln	Bristol	Peter Svensen (Round Pond quarry).	Paving blocks, monuments.
Oxford	Fryeburg	Eagle Gray Granite Co. (Osgood quarry).	Rough construction, monument bases, flagging.
Waldo	Lincolnville	W. E. Dornan & Son	Monuments.
Washington	Addison	Maine Black Diamond Granite Co. (Indian Black Diamond quarry).	Do.
	Calais	C. L. Young	Do.
	Jonesport	Rockport Granite Co.	Rough construction.
	Red Beach	Red Beach Granite Co.	Monuments.
York	Biddeford	Frank Morin	Buildings, monuments, curbing.
	North Berwick	Minutti Bros.	Monuments.

The Geological Survey is also informed that plans are under way by the George A. Fuller Co., New York City, to operate quarries at Hallowell and Stonington (Deer Isle) in order to quarry stone for the courthouse in New York City, for which this company has the building contract.

Granite produced in Maine, 1860 to 1921.

Year.	Number of plants.	Building.				Monumental.				Paving blocks.		Curbing and flagging.		Other uses.		Total.	
		Rough.		Dressed.		Rough.		Dressed.									
		Cubic feet.	Value.	Cubic feet.	Value.	Cubic feet.	Value.	Cubic feet.	Value.	Number.	Value.	Linear feet.	Value.	Short tons.	Value.	Short tons (approximate).	Value.
1860																	$295,280
1880	68															183,000	1,175,286
1887																	a 565,000
1888																	b 959,100
1889	153	856,786	$145,117	1,819,741	$839,125	231,972	$299,158			17,704,915	$824,113		$103,836	470	$14,490	563,000	2,225,839
1891																	2,200,000
1892																	2,300,000
1893																	1,274,954
1894																	1,551,036
1895																	1,400,000
1896			c 187,855		505,238		(d)		$80,564		344,101		70,433		7,300	210,000	1,195,491
1897	66		c 228,663		585,826		(d)		56,576		172,637		71,625			180,000	1,115,327
1898	75		c 242,834		380,970		(d)		84,426		212,109		94,074		18,208	202,000	1,032,621
1899			c 302,731		637,616		(d)		77,350		184,084		94,237		25,064	272,000	1,321,082
1900			c 286,781		887,786		(d)		98,380		145,966		96,271		53,389	232,000	1,568,573
1901			407,418		1,501,797		24,475		76,276		401,189		124,535		167,426	420,000	2,703,116
1902	110		485,217		1,435,803		52,836		155,305		354,530		122,528		53,231	378,000	2,659,450
1903	112		267,778		1,300,608		43,961		159,478		639,607		108,842		66,491	402,000	2,586,765
1904	107		126,959		1,592,132		31,066		86,610	9,808,465	426,463		81,247		56,032	280,000	2,400,509
1905	106		434,402		1,648,687		77,543		69,910	8,188,596	324,858		84,421		73,974	365,000	2,713,795
1906	91		349,668		1,413,486		78,802		192,577	8,658,437	336,979		72,085		116,424	342,000	2,560,021
1907	88		318,816		1,007,572		60,263		166,789	6,292,753	355,462		157,890		79,628	316,000	2,146,420
1908			293,371		1,055,989		63,799		111,774	8,005,662	368,715		82,805		51,055	296,000	2,027,508
1909	85		237,597		1,152,677		31,375		39,704	6,137,682	262,895		88,509		126,767	300,000	1,939,524
1910			299,070		954,513		90,194		200,105	10,893,020	548,374		114,648		108,826	370,000	2,315,730
1911	82	1,196,910	263,105	605,049	1,274,048	65,519	44,181	22,556	68,399	10,040,523	467,398	200,599	83,632	48,000	56,271	322,000	2,257,034
1912	77	932,165	307,122	215,578	563,482	73,477	40,875	25,216	65,722	12,795,125	670,520	218,523	110,509	35,000	45,149	310,000	1,803,679
1913	70	682,498	208,028	331,939	633,140	66,886	39,224	19,208	27,189	13,266,644	702,318	193,836	91,440	72,000	88,940	315,000	1,790,279
1914	50	495,579	144,407	456,818	794,313	141,482	61,611	16,884	25,697	10,708,177	529,853	183,349	82,071	68,000	79,158	274,000	1,717,110
1915	57	369,955	90,220	140,045	265,992	96,671	58,762	16,346	38,054	10,910,032	495,327	180,086	88,001	17,000	25,927	195,000	1,062,283

1916	51	501,349	152,792	172,880	274,295	83,800	51,337	20,025	48,930	8,823,252	430,753	180,058	96,510	16,000	13,868	185,000	1,068,485
1917	39	262,925	100,941	144,240	425,363	58,629	49,658	7,651	17,564	8,781,816	569,300	138,976	74,821	18,000	16,882	158,000	1,254,529
1918	35	198,590	58,305	152,485	579,012	56,658	51,846	7,386	19,518	6,573,847	432,075	97,120	46,374	21,000	24,613	131,000	1,211,743
1919	44	243,696	142,301	48,599	223,863	75,503	90,141	60,688	172,396	8,331,436	547,128	64,956	57,980	18,114	40,665	149,820	1,274,474
1920	35	276,450	275,849	61,530	449,810	95,650	112,432	49,230	165,456	8,676,350	726,280	66,640	65,754	17,870	29,071	154,100	1,824,652
1921	37	e 125,460	e 169,345	(e)	(e)	85,920	97,585	9,190	43,010	10,365,600	993,939	67,200	57,220	26,800	25,531	163,240	1,386,660

a Includes output at Berwick, Bristol, Deer Isle, Mount Desert, Mount Waldo, Norridgewock, and South Thomaston.

b Includes output at Addison, Biddeford, Deer Isle, Frankfort, Franklin, North Jay, Red Beach, Round Pond, Wayne, and Sullivan.

c Reported as "rough stone," and probably includes rough monumental stone.

d See "Rough building."

e Rough building includes dressed building.

NEW HAMPSHIRE.

New Hampshire, notwithstanding its nickname "Granite State," usually ranks below Massachusetts, Maine, and Vermont in quantity of granite produced, but in 1921 it made a larger output than Vermont. Records show that stone from boulders at Concord was used in 1812 for the construction of the New Hampshire State prison and in 1816 to 1819 for the construction of the statehouse, but it was in 1840 that the ledges of the famous Rattlesnake Hill were first opened. Few quarries, however, were operated until after 1860. At Milford quarries were opened in 1813, and stone was drawn by oxen to neighboring towns in 1833; but it was not until after 1851, when railroad transportation was available, that stone was shipped any distance. Quarries were opened at Marlboro in 1812, at Nashua in 1822, at Fitzwilliam in 1860–1879, and at Allentown in 1876. Granite from New Hampshire, like that from Vermont, has been sold only to a small extent for crushed stone and riprap work. The demand for the product, chiefly as building and monumental stone and paving blocks, has therefore not shown the sharp changes indicated for the other States.

In 1921 granite was produced at the following localities in the State:

Granite quarries operated in New Hampshire in 1921.

County.	Nearest town.	Operator.	Use of stone.
Carroll	Redstone	Maine & New Hampshire Granite Corporation.	Buildings, monuments, mausoleums, riprap, crushed stone, grindstones.
Cheshire	Fitzwilliam	Milford Pink-Victoria White Granite Co.	Mausoleums, buildings, monuments.
	do	E. M. Thompson (Angier quarry).	Monuments.
	do	Edw. Yon & Son	Do.
Hillsborough	Brookline	Sneck & Maki	Paving blocks.
	Milford	Blue Quarry Co	Monuments.
	do	O. A. Ciampo (Ball Hill quarry).	Monuments, paving blocks.
	do	E. L. Kittredge	Buildings, monuments, curbing, paving blocks.
	do	Lovejoy Granite Co	Buildings, monuments, paving blocks, rubble, curbing.
	do	New Westerly Granite Co.	Monuments, paving blocks.
	do	Pease Co	Monuments, paving blocks, curbing, riprap.
	do	Roberts Bros	Paving blocks.
	do	Smalley-Souhegan Granite Co.	Monuments, paving blocks.
	do	Tonella & Sons (King & Queen quarry).	Buildings, monuments, paving blocks.
	do	Young's Sons & Co	Monuments.
	North Brookline	Crown Hill Quarry Co	Monuments, paving blocks.
	Pratt	Carl J. Westberg	Paving blocks, curbing.
	South Brookline	John R. Richards	Monuments.

Granite quarries operated in New Hampshire in 1921—Continued.

County.	Nearest town.	Operator.	Use of stone.
Merrimack	Concord	Lapierre Bros	Monuments.
	do	New England Granite Works.	Buildings, monuments, curbing, rubble, paving blocks.
	do	Perry Bros	Monuments, paving blocks.
	do	John Swenson Granite Co.	Monuments, buildings, mausoleums, curbing, paving blocks, riprap.
	Hooksett	Geo. H. Shirley	Curbing.
	Suncook (Allentown)	Chas. A. Bailey	Paving blocks, rubble, curbing, crushed stone, dust for artificial stone.

Granite produced in New Hampshire—1860–1921.

Year.	Number of plants.	Building.				Monumental.				Paving blocks.		Curbing and flagging.		Crushed.		Other.		Total.	
		Rough.		Dressed.		Rough.		Dressed.											
		Cubic feet.	Value.	Cubic feet.	Value.	Cubic feet.	Value.	Cubic feet.	Value.	Number.	Value.	Linear feet.	Value.	Short tons.	Value.	Short tons.	Value.	Short tons (approximate).	Value.
1860	—																		$23,540
1880	39																	159,400	303,066
1887																			[a] 195,000
1888																			[b] 104,800
1889	78	110,467	$8,409	1,306,331	$324,567	151,711	$135,029			2,043,739	$87,569	900,000	$164,687			8,000	$7,270	240,000	727,531
1891																			750,000
1892																			725,000
1893																			442,424
1894											24,000								724,702
1895											16,823								480,000
1896			[c] 151,975		194,926		(d)		$119,460		26,355		4,700				550	44,000	497,966
1897	48		[c] 161,190		217,486		(d)		214,803		26,177		15,525				6,510	63,000	641,691
1898	49		[c] 162,916		193,162		(d)		247,642		47,650		20,554		$8,690		2,981	87,000	683,595
1899			[c] 180,109		272,368		(d)		256,397		54,099		23,437		7,480		8,746	86,000	802,636
1900			[c] 193,471		299,418		(d)		242,026		58,512		37,427		15,126		24,666	132,000	870,646
1901			156,832		363,957		52,231		171,239		112,581		28,708		25,223		24,723	165,000	935,494
1902	51		148,579		471,337		57,335		289,400		101,548		22,668		26,550		29,680	178,000	1,147,097
1903	44		115,524		282,014		57,775		252,044		58,708		36,643		16,407		35,398	145,000	854,513
1904	48		124,186		393,144		74,478		214,578	1,892,260	65,151		17,810		15,521		22,619	131,000	927,487
1905	45		76,609		254,928		129,685		227,799	2,084,202	76,822		27,409	26,681	16,467		28,652	139,000	838,371
1906	37		90,751		342,336		91,044		98,622	2,298,145	89,878		62,629	29,630	20,694		22,177	141,000	818,131
1907	31		49,831		224,269		90,352		133,601	1,782,406	74,978		46,809	27,187	18,324		9,557	103,000	647,721
1908			92,738		355,628		111,253		136,772	2,842,206	103,833		35,899	18,454	16,455		14,450	125,000	867,028
1909	40		143,757		521,299		70,018		192,762	4,997,161	170,434		53,673	34,041	30,789		32,729	270,000	1,215,461
1910			101,672		576,271		64,321		153,373	6,772,224	233,836		62,651	27,529	19,201		28,331	220,000	1,239,656
1911	34		77,508		380,171		63,188		170,169	5,613,841	212,526		62,133	24,721	16,968		34,609	197,000	1,017,272
1912	35	161,324	70,533	228,602	571,661	84,160	66,879	45,214	168,784	8,153,800	297,256	205,861	80,338	31,470	25,630	55,000	30,407	227,000	1,311,488
1913	36	161,583	51,961	189,020	553,333	119,752	93,662	52,783	194,995	10,979,474	451,545	217,480	71,673	20,305	16,841	90,000	48,761	281,000	1,482,771
1914	36	159,179	84,680	166,044	491,483	123,062	93,466	64,881	211,503	9,449,108	391,480	200,747	74,574	26,444	18,011	25,000	18,128	206,000	1,383,325
1915	34	130,322	69,089	221,179	549,702	87,687	62,349	62,033	218,873	4,243,753	205,456	212,226	77,644	29,612	23,417	30,000	27,619	159,000	1,234,149
1916	28	128,062	58,441	170,729	436,954	76,625	56,019	45,311	210,170	5,486,815	247,177	187,564	79,636	25,596	22,431	35,000	30,982	115,000	1,141,810
1917	21	89,988	78,859	88,150	258,749	81,476	64,549	74,902	187,973	4,873,413	213,099	123,647	59,084	38,040	39,761	8,000	7,626	133,000	909,700
1918	18	17,379	8,095	36,825	135,155	143,303	189,604	89,840	393,557	3,980,651	213,688	18,480	28,301	17,083	26,024	9,089	8,904	93,000	1,003,328
1919	24	95,351	78,858	71,141	347,897	181,892	208,840	83,463	397,975	4,510,958	287,718	46,887	79,378	13,261	26,027	2,579	16,511	104,690	1,443,204
1920	26	62,380	26,131	80,650	705,897	153,090	289,670	78,340	432,909	5,209,180	372,419	143,500	145,160	15,690	26,847	7,330	8,432	120,600	2,007,465
1921	24	26,720	27,074	47,530	391,934	67,340	154,129	32,230	286,009	4,778,900	331,456	145,370	117,896	3,750	6,680	7,380	7,099	87,460	1,322,277

[a] Includes output at Concord and Fitzwilliam.
[b] Includes output at Concord, Milford, and Nashua.
[c] Reported as "rough stone," probably includes rough monumental stone.
[d] See "Rough building."

VERMONT.

Records show that stone from the vicinity of Barre, Vt., was used to build houses as early as 1814. In 1824 millstones were furnished to Canadian and New England mills, and in 1833 stone was drawn from Barre to Montpelier to build the State capitol, which has recently been enlarged by stone from the same quarries. The report of the Eighth Census (1860) does not record any granite production from Vermont, but the report of the Tenth Census (1880) shows that quarries were opened at Barre as early as 1835 and 1840 and at Ryegate in 1850. The first factor in the rise of Vermont to prominence in the granite industry was the extension in 1875 of the Central Vermont Railway to Barre. In 1888 a railroad was built to the quarries, saving hauling that had been mostly done by ox teams. In 1880 the census report showed a production from Vermont of 187,140 cubic feet of granite, with a value of $59,675. In 1887 the Barre quarries produced 300,000 cubic feet of stone, valued at $225,000, and in 1888 stone valued at $276,000 was produced at Barre and $3,000 at Woodbury. The Eleventh Census (1889) showed 53 quarries in operation and an output of more than 1,000,000 cubic feet. The largest number of quarries at Barre were opened between 1882 and 1890.

The Dummerston quarries were developed in 1877. In Caledonia County quarries at Hardwick and South Ryegate were opened between 1850 and 1875, but the principal development here also took place after the building of a railroad in 1896. The Williamstown quarries were developed in 1889; the Bethel quarries in 1902 (quarries were opened here in 1868); the Woodbury quarries in 1880; and the Mount Ascutney quarries in 1906. The other quarries in the State are smaller and less known and have not had much influence on the total production. Barre has become the largest center for monumental stone in the country if not in the world. Little of the stone quarried is milled or dressed by the quarrymen, most of it being sold in rough blocks to manufacturers for dressing. The magnitude of the entire granite business in 1917 and 1918 in the Barre district is shown in the following tabular statement furnished by Athol R. Bell, secretary of the Barre Quarries & Manufacturers' Association, and published in the report on stone in Mineral Resources of the United States, 1918. The district includes Barre, Williamstown, East Barre, Montpelier, West Berlin, Northfield, and Waterbury. The years 1917 and 1918 are taken as representing more normal years than 1920 and 1921.

Estimated output of monumental granite in the Barre district in Vermont in 1917–18.[a]

	1917	1918
Total quarry output (rough stock)....cubic feet..	1,560,000	1,654,800
Shipped out of Barre district in rough....do....	260,000	248,222
Manufactured in Barre district....do....	1,300,000	1,406,578
Light-stock consumption in district....do....	800,000	879,111
Dark-stock consumption in district....do....	500,000	527,467
Number of cutters in district....	2,550	1,500
Average daily wage....	$5.00	$5.00
Average number of days worked annually....	280	260
Total pay roll for year....	$3,570,000	$4,100,000
Estimated overhead—50 per cent cutters' wages....	1,785,000	2,050,000
Estimated light-stock valuation, 800,000 cubic feet, at $1.25....	1,000,000	....
Estimated dark-stock valuation, 500,000 cubic feet, at $1.45....	725,000	....
Estimated polishing cost of 500,000 feet, 1 cubic foot averaging 2 cubic feet, at $1..	1,000,000	....
Output from saws—one saw equaling 10 men—13 saws in district take place of 130 men at average cost of $6.50 per man and working 280 days a year....	236,000	....
	8,316,000	....

[a] These estimates do not include production by other machinery, such as lathes and sand-blast machines, nor do they include valuation of rough stock shipped outside of the Barre district.

Mr. Bell states that 56 quarries were operated during 1918. Regarding industrial conditions in 1918, he says:

The Barre granite industry in 1918 was naturally subject to a good many of the proscriptions which necessity imposed upon nonessential industries. Our members, while realizing that the loss to them would be measurably irreparable, patriotically cooperated with the Government in sending men, many of them skilled pneumatic-tool operators, to the shipyards. In addition there was the prevailing shortage of unskilled labor at the quarries, and of course many men were with the colors.

The arduous winter of 1917–18 cut down the number of working days to 260, the average being 280. Yet the steady introduction of labor-saving machinery partially closed up the gap caused by the decimation of man power in the industry, prolonged suspensions due to extreme weather and fuel orders, and the inevitable shortage of cars.

The stone quarried at Woodbury, which is the center next in importance to Barre, is largely milled and dressed by the producer, as is the Dummerston stone. The accompanying tables and diagrams show the present depressed condition in the Vermont granite industry. The total output in 1921 was less than it was 32 years ago, with half as many quarries in operation, but the value of the product was over six times as great. The producers in 1921 were as follows:

Granite quarries operated in Vermont in 1921.

County.	Nearest town.	Operator.	Use of stone.
Caledonia....	Groton....	Rinaldo Tonelli....	Monuments.
	Hardwick....	August Ahonen....	Do.
	....do....	Allen Badger....	Do.
	....do....	Fadden & Gonyear....	Do.
	South Ryegate....	New Barre Granite Co....	Do.
	....do....	Ryegate Granite Works Co.	Buildings, monuments.
Orange....	Williamstown....	James K. Pirie estate....	Monuments.
Orleans....	Newport....	A. C. Lacasse Granite Co..	Do.
	Orleans....	O. L. Searles....	Do.

Granite quarries operated in Vermont in 1921—Continued.

County.	Nearest town.	Operator.	Use of stone.
Washington	Adamant	Hughes Granite & Quarry Co.	Monuments.
	Barre	Boutwell, Milne & Varnum Co.	Buildings, monuments.
	do	Capital Hill Quarry Co. (Inc.)	Buildings, monuments, paving blocks.
	do	Jones Bros. Co	Monuments, mausoleums.
	do	Littlejohn & Milne Quarry Co. (Inc.).	Do.
	do	E. L. Smith & Co	Monuments.
	do	Wetmore & Morse Granite Co.	Monuments, mausoleums.
	Cabot	Cabot Granite Co	Monuments.
	Websterville	Standard Granite Co	Monuments, mausoleums.
	do	Sunnyside Granite Co	Monuments.
	do	Wells-Lamson Quarry Co	Do.
	Woodbury	E. R. Fletcher	Buildings.
	do	L. S. Robie	Monuments.
	do	Woodbury Granite Co	Buildings, monuments.
Windham	West Dummerston	Presbrey-Leland Quarries (Inc.)	Monuments, riprap.
Windsor	Bethel	Woodbury Granite Co	Buildings, crushed stone.

Granite produced in Vermont, 1880–1920.

Year.	Number of plants.	Building.				Monumental.				Paving blocks.		Other.		Total.	
		Rough.		Dressed.		Rough.		Dressed.							
		Cubic feet.	Value.	Cubic feet.	Value.	Cubic feet.	Value.	Cubic feet.	Value.	Number.	Value.	Short tons.	Value.	Short tons (approximate).	Value.
1880	12													16,000	$59,675
1887														a 25,000	a 225,000
1888															b 279,000
1889	53	197,834	$41,713	236,759	$15,198	373,020	$412,287			883,096	$45,643	4,000	$37,029	90,000	581,870
1891															700,000
1892															675,000
1893															778,459
1894											32,711				893,956
1895											30,702				1,007,718
1896			(c)				d 460,128		$404,398		30,990			86,100	895,516
1897	48		(c)		283,167		d 430,121		341,034		16,770		3,208	91,000	1,074,300
1898	51		(c)		113,922		d 531,634		416,878		4,446		17,338	105,000	1,084,218
1899			(c)		125,775		d 563,475		509,358		3,500		10,859	114,000	1,212,967
1900			(c)		49,763		d 526,370		527,053		225		10,377	112,000	1,113,788
1901			208,825		16,343		534,755		354,563		16,304		115,038	152,000	1,245,828
1902	74		28,845		289,567		756,007		453,187		2,855		39,962	167,000	1,570,423
1903	61		103,353		346,293		828,508		481,346		28,839		21,840	144,000	1,810,179
1904	71		83,148		912,801		797,830		615,057	382,758	14,745	34,000	24,398	169,000	2,447,979
1905	63		188,391		1,093,688		778,681		471,093	418,898	16,628	27,000	23,369	172,000	2,571,850
1906	53	80,062	47,154	426,739	1,422,862	1,215,583	993,220	126,661	451,222	282,930	9,557	7,000	10,810	164,000	2,934,825
1907	55	43,293	29,764	304,482	1,009,353	1,202,908	1,122,063	139,143	515,859	171,000	5,330	17,000	11,520	160,000	2,693,889
1908	54	104,236	79,711	173,321	676,067	1,235,929	1,095,223	165,906	582,051	58,200	1,547	24,000	17,334	164,000	2,451,933
1909	53	213,740	128,233	382,230	1,035,075	1,343,834	1,154,826	173,742	479,415	163,885	5,824	9,000	8,371	186,000	2,811,744
1910	44	134,594	76,807	246,969	887,430	1,358,989	1,197,187	141,659	495,449	826,071	25,915	18,130	11,686	183,000	2,694,474
1911	48	104,284	54,552	192,290	795,083	1,417,128	1,290,807	156,789	543,508	915,766	27,177	32,000	19,592	197,000	2,730,719
1912	40	49,197	34,433	390,700	1,323,787	1,409,767	1,367,149	105,306	286,503	344,015	12,016	41,000	24,066	210,000	3,047,954
1913	40	55,667	43,621	549,565	2,008,240	1,482,492	1,453,818	71,053	239,187	70,654	3,162	55,000	34,207	234,000	3,782,235
1914	39	21,679	15,705	387,567	1,321,534	1,497,511	1,509,795	81,109	242,227	75,000	3,375	46,000	27,821	212,000	3,120,457
1915	34	18,170	11,394	231,169	1,088,950	1,334,106	1,334,427	87,281	322,268	34,800	1,430	33,000	20,261	182,000	2,778,730
1916	37	41,213	30,930	159,031	641,927	1,487,243	1,547,075	87,463	320,919	(e)	(e)	14,000	19,728	161,000	2,560,579
1917	36	(f)	(f)	f 197,151	f 602,785	1,478,623	1,693,653	141,841	506,856	1,191,762	38,781	3,000	8,540	195,000	2,850,615
1918	24			(e)	(e)	1,481,927	2,043,826	81,938	495,437	(e)	(e)	16,000	150,389	146,000	2,689,652
1919	29	(f)	(f)	f 31,891	f 54,950	1,480,903	3,227,888	90,209	744,234	41,500	2,800	1,006	1,863	133,627	4,031,735
1920	30	(f)	(f)	f 123,320	f 526,418	g 1,338,260	g 4,251,651	(g)	(g)	99,500	7,846	3,380	8,020	127,230	4,793,935
1921	26	g 169,410	g 1,278,228	(g)	(g)	703,690	2,006,431	49,900	530,100	(e)	(e)	6,450	21,012	82,500	3,835,771

a Production at Barre.
b Production at Barre and Woodbury.
c See "Rough monumental."
d Reported as "rough stone" and probably includes rough building stone.
e Included under "Other."
f Rough stone included under dressed stone.
g Dressed stone included under rough stone.

MASSACHUSETTS.

Massachusetts has always been the largest producer of granite among the New England States, but on account of the large amount of low-priced products—paving blocks, curbing, crushed stone, breakwater stone, jetty stone, riprap, and other rough construction materials—supplied from the quarries, it has at times been exceeded in total value of output by Maine, and since 1906 by Vermont.

As previously stated, the real granite industry of this State began with the opening of the Quincy quarries in 1824 and the building of the Bunker Hill Monument and the railway or tramway from the quarries to tidewater. The development of quarry methods from quarrying and handling by hand power to the hand derrick, the application of steam to hoists, drills, pumps, etc., followed by the use of compressed air and finally electricity in both quarry and shop has been a direct result of this at that time enormous enterprise. The quarries at Quincy have been in continuous operation since they were opened. In 1837, according to Doctor Pattee's History of Quincy, the output of the Quincy quarries was 64,590 tons of stone, valued at $248,737, and there were 533 employees. In 1845 there were 526 employees, and the value of the output was $324,500. In 1865 ten quarries produced $271,880 worth of stone and employed 306 men. The production at Quincy for 1887, 1888, and 1916–21 has been as follows, according to reports to the United States Geological Survey:

Granite produced at Quincy, Mass., 1887, 1888, and 1916–1921.

Year.	Number of plants.	Short tons (approximate).	Value.
1887			$520,000
1888			500,000
1916	10	62,000	460,263
1917	10	29,000	398,196
1918	5	26,000	336,843
1919	8	32,000	614,005
1920	8	27,000	674,233
1921	6	14,000	311,178

Stone was also quarried at an early date at the Chelmsford quarries, but the quarries on Cape Ann—at Gloucester, Rockport, Lanesville, and Pigeon Cove—were operated soon after the Quincy quarries and from their admirable location for transportation have furnished, besides high-grade monumental and building stone, an enormous quantity of stone for river and harbor work and street work.

According to the report of the Tenth Census, quarries in operation in 1880 were opened in Massachusetts at the places and dates which are given on page 456.

Berkshire County:
Chester (Becket), 1878–1880.
Bristol County:
New Bedford, 1860.
Fall River, 1840–1873.
Essex County:
Rockport, 1830–1870.
Lawrence, 1847.
Gloucester, 1851–1878.
Hampden County:
Monson, 1839.
Middlesex County:
Graniteville, 1860.
Lowell, 1876.
Westford (Chelmsford), 1845–1880.
Norfolk County:
Quincy and West Quincy, 1810–1879.
Worcester County:
Fitchburg, 1831–1876.
Milford, 1869.
Leominster, 1872.

Quarries in operation in Massachusetts in 1921.

County.	Nearest town.	Operator.	Use of stone.
Berkshire	Chester	Chester Granite Quarries (Inc.)	Monuments.
	Lee	Jos. Newall & Co.	Monuments, curbing, paving blocks.
	Lenox	Mrs. Margaret Cowhig	Crushed stone.
Bristol	Acushnet	Blue Stone Quarry Co.	Crushed stone.
	Dartmouth	North Dartmouth Granite Co.	Rough construction, curbing, paving blocks.
	Fall River	Wm. H. Beattie	Buildings, crushed stone.
	....do	Carey Quarry & Construction Co.	Buildings, paving blocks, curbing.
	....do	Fall River Granite & Quarry Co.	Rough construction, paving blocks, curbing.
	New Bedford	Sullivan Granite & Construction Co.	Buildings, paving blocks, curbing, riprap, crushed stone.
Essex	Lanesville	Cape Ann Granite Corporation.	Buildings, paving blocks, curbing.
	Lawrence	Holland Construction Co.	Crushed stone.
	Rockport	J. Leonard Johnson	Paving blocks, curbing.
	Rockport and Gloucester	Rockport Granite Co.	Rough construction, buildings, monuments, paving blocks, curbing, rubble, crushed stone.
Hampden	Monson	Wm. N. Flynt Granite Co.	Curbing.
Hampshire	Northampton	City of Northampton	Crushed stone.
Middlesex	Carlisle	O'Rourke Bros	Monuments.
	Chelmsford	Orrin O. Luke (Kidder quarry).	Paving blocks.
	Graniteville	Chas. E. Conture (Wright quarry).	Curbing, riprap.
	....do	H. N. Fletcher	Curbing.
	....do	Lewis P. Palmer & Sons	Paving blocks, curbing, crushed stone.
	Lowell	Frank A. Malorey (Fletcher quarry).	Paving blocks, curbing.
	Townsend	Duncan Rusk (West Townsend quarry).	Buildings.
	Westford	C. W. Carkin	Paving blocks, curbing.
	....do	Arthur DeCarteret (Old Prescott quarry).	Curbing.
	....do	H. E. Fletcher Co.	Buildings, bridges, monuments, paving blocks, curbing, rubble, crushed stone.
	....do	H. W. Hildreth	Paving blocks, curbing.
	....do	Thos. J. LeMasurier (Oak Hill quarry).	Curbing.
Norfolk	Cohasset	Louis C. Tiffany	Memorials.
	Quincy	Elkhill & Bishop	Monuments, riprap.
	....do	A. Falconer & Co.	Monuments.
	....do	C. H. Hardwick & Co.	Construction, monuments, paving block stock, riprap.
	....do	Old Colony Crushed Stone Co.	Crushed stone.
	....do	Quincy Quarries Co. (Hitchcock quarries).	Monuments.
	West Quincy	Granite Railway Co.	Monuments, riprap.
	....do	J. S. Swingle (Badger, Elcock, and Mannix quarries).	Monuments.

Quarries in operation in Massachusetts in 1921—Continued.

County.	Nearest town.	Operator.	Use of stone.
Norfolk	Weymouth	Bates Bros. Seam Face Granite Co.	Buildings.
	Wrentham	R. H. Curry (High Rock quarry).	Buildings, curbing.
Plymouth	East Weymouth	J. E. L. Miller	Buildings.
	Hingham	Plymouth Quarries, Inc.	Buildings, crushed stone.
	Lakeville	Frank C. Taylor	Construction.
Suffolk	West Roxbury	West Roxbury Trap Rock Co.	Crushed stone.
Worcester	Fitchburg	Benj. F. McCauliff (Rollstone Hill quarry).	Rough construction, paving blocks, curbing, crushed stone.
	Milford	Milford Pink-Victoria White Granite Co.	Buildings, monuments, mausoleums.
	do	Wm. M. Sherman	Buildings, monuments.
	do	Geo. A. Fuller Construction Co. (operating Bay State Pink quarries in 1922).	Buildings.
	North Uxbridge	Blanchard Bros. Granite Co.	Rough construction, buildings, monuments, curbing, rubble, crushed stone.
	Whitinsville	Carrick & Gough	Buildings, monuments, curbing.
	Worcester	Antonelli Bros. ("Belmont Hill quarry").	Rough construction, crushed stone.

Granite produced in Massachusetts, 1880–1921.

Year.	Number of plants.	Building.				Monumental.				Paving blocks.		Curbing and flagging.		Crushed.		Other.		Total.	
		Rough.		Dressed.		Rough.		Dressed.											
		Cubic feet.	Value.	Cubic feet.	Value.	Cubic feet.	Value.	Cubic feet.	Value.	Number.	Value.	Linear feet.	Value.	Short tons.	Value.	Short tons.	Value.	Short tons (approximate).	Value.
1880	92																	388,000	$1,329,315
1887																			a 881,000
1888																			b 1,741,600
1889	151	6,896,991	$1,395,491			509,087	$497,438			6,106,016	$378,627					c 120,000	c $231,947	805,000	2,503,503
1891																			2,600,000
1892																			2,200,000
1893																			1,631,204
1894											593,726								1,994,830
1895											496,544								1,918,894
1896					$1,108,736				$185,987		324,784		$23,745				13,721	282,000	1,656,973
1897	84		d 539,163		678,616		(e)		229,346		243,750		25,126		$4,900		15,168	305,000	1,736,069
1898	89		d 393,331		545,213		(e)		203,487		127,483		245,134		44,210		54,789	337,000	1,613,647
1899			d 499,781		533,004		(e)		257,820		226,909		88,685		31,579		94,281	381,000	1,732,059
1900			d 568,119		429,077		(e)		80,573		267,148		89,692		42,116		140,335	462,000	1,617,060
1901			333,047		455,535		236,327		236,273		364,721		146,325		63,744		249,738	558,000	2,085,710
1902	115		387,167		965,342		412,172		381,872		358,398		126,798		70,170		378,938	742,000	3,080,857
1903	105		273,291		648,471		374,544		211,175		349,066		83,197		130,057		281,226	660,000	2,351,027
1904	110		200,300		876,517		365,607		209,077	5,678,562	320,714		147,316		119,308		315,909	642,000	2,554,748
1905	98		183,345		824,999		424,944		189,131	6,594,650	270,308		98,170		130,691		129,731	486,000	2,251,319
1906	89		220,121		1,750,695		435,280		289,334	4,936,078	199,457		93,549		155,843		183,137	600,000	3,327,416
1907	90		267,984		907,119		337,016		66,578	5,995,040	319,037		92,530		134,968		203,545	581,000	2,328,777
1908			180,063		720,796		358,830		115,386	6,134,648	261,880		94,327		125,711		170,470	517,000	2,027,463
1909	82		212,075		542,441		508,805		298,235	6,878,872	308,203		117,371		101,682		75,807	415,000	2,164,619
1910			202,375		349,431		461,814		32,600	4,532,685	201,425		121,406		76,913		121,790	400,000	1,567,754
1911	89		365,464		607,358		373,764		4,600	9,000,073	432,600		146,371		125,303		306,164	757,000	2,361,624
1912	81		190,585		778,403		424,813		20,700	7,070,082	358,876		111,054		150,169		185,679	590,000	2,220,279
1913	83		198,974		730,404		400,652		30,246	7,885,001	395,390		134,516		185,260		145,188	528,000	2,220,630

1914	83	....	46,321	....	710,171	....	451,095	....	34,750	8,325,520	418,671	....	144,086	....	176,531	....	109,792	491,000	2,091,417
1915	78	....	168,264	....	768,957	....	419,900	....	12,689	5,580,441	283,612	....	136,923	....	191,983	....	88,875	488,000	2,071,203
1916	76	984,872	192,896	334,267	636,552	471,592	412,778	10,408	30,685	5,404,377	287,640	312,221	167,399	168,015	185,375	89,221	83,825	486,000	1,997,150
1917	65	570,251	143,847	291,370	495,156	335,956	394,644	30,782	85,924	6,277,073	365,874	312,060	174,593	166,974	215,743	63,945	56,730	420,000	1,932,511
1918	42	470,376	163,389	227,797	527,773	f400,475	f436,383	(f)	(f)	4,523,302	284,634	76,162	85,644	120,991	232,046	64,613	75,527	378,000	1,805,396
1919	45	239,965	212,294	86,075	254,176	495,012	741,039	11,546	104,781	6,122,089	513,422	196,980	175,710	213,371	448,354	21,682	28,162	383,760	2,477,938
1920	49	401,310	352,633	128,390	786,926	345,270	742,118	27,470	137,018	5,509,540	511,961	193,620	226,703	218,260	564,224	16,580	48,979	383,340	3,370,562
1921	49	362,310	262,763	118,160	362,770	184,700	382,848	13,460	136,345	6,276,850	667,685	255,920	302,055	186,960	427,373	60,410	77,427	387,410	2,619,266

a Includes production at Milford, Quincy, and Rockport.
b Includes production at Fitchburg, Northbridge, Quincy, Rockport, Sherbourne, Westford, West Quincy, and Worcester.
c Includes stone for street work (except paving blocks).
d Reported as "rough stone" and includes rough monumental stone.
e See "Rough building."
f Dressed stone included under rough stone.

CONNECTICUT.

The granite industry in Connecticut has declined relatively more than in any other State in New England. In the five years 1917–1921 the output decreased 65 per cent, and the production for 1921 was about one-thirtieth of that in 1889. In 1889 there were 49 quarries in operation; in 1921, 11. Much of the Connecticut granite has been used for small work, such as copings, sills, lintels, steps, foundations, cross walks, curbings, and sidewalks, and the use of concrete for work of this class has closed practically all the small quarries in the State. No granite quarries have been operated in this State for extensive riprap, breakwater, or jetty work in recent years, and this has also contributed to the decrease in output. The most important operations in 1921 were at Stony Creek, Waterford, Niantic, and buildings and monumental stone were the chief products.

The activity of quarries in Connecticut in early years is shown by the report of the Tenth Census (1880), which gave the following dates of opening of quarries in operation at that time:

Fairfield County:
- Greenwich, 1830–1850.
- Bridgeport, 1873.

Hartford County:
- Glastonbury, 1850.

Litchfield County:
- Thomaston, 1855.

Middlesex County:
- Haddam, 1800.
- Middletown, 1830.

New Haven County:
- Ansonia, 1848.
- Leete Island, 1870.
- Stony Creek, 1878.

New London County:
- Niantic, 1832.
- Waterford, 1835.
- Groton, 1840–1869.
- Lyme, 1875–1876.

Windham County:
- East Killingly, 1842.
- Sterling, 1855–1877.
- Oneco, 1868.
- Willimantic, 1877.

Granite quarries in operation in Connecticut in 1921.

County.	Nearest town.	Operator.	Use of stone.
Fairfield	Bridgeport	Burns Co	Crushed stone.
Hartford	Glastonbury	Glastonbury Granite Works (Inc.)	Rough construction, curbing.
Litchfield	Thomaston	Plymouth Granite Co	Buildings.
New Haven	Stony Creek	Millford Pink-Victoria White Granite Co.	Buildings, monuments, mausoleums.
	Millstone	Henry Gardiner	Monuments, riprap, paving blocks.
New London	Waterford	Booth Bros. & Hurricane Isle Granite Co.	Buildings, monuments, paving blocks, riprap.
	Niantic	Connecticut Pink Quarries Co.	Monuments.
	do	A. Malnati & Co	Do.
	do	Wm. Sieverts	Do.
Windham	Oneco	R. B. Marriott & Sons	Buildings, curbing, paving blocks.

Granite produced in Connecticut, 1880–1921.

Year.	Number of plants.	Building.				Monumental.				Paving blocks.		Curbing and flagging.		Crushed.		Other.		Total.	
		Rough.		Dressed.		Rough.		Dressed.											
		Cubic feet.	Value.	Cubic feet.	Value.	Cubic feet.	Value.	Cubic feet.	Value.	Number.	Value.	Linear feet.	Value.	Short tons.	Value.	Short tons.	Value.	Short tons (approximate).	Value.
1880	32																	213,276	$407,225
1887																			a 210,000
1888																			b 90,000
1889	53	571,031	$65,659	2,358,286	$758,915	148,108	$111,155			761,100	$40,683	158,000	$68,578			16,000	$16,212	322,000	1,061,202
1891																			1,167,000
1892																			700,000
1893																			652,459
1894																			504,390
1895																			779,361
1896					632,432				$91,121		32,592				$35,580		2,600	214,000	794,325
1897	27		c 248,955		148,414		(d)		94,271		76,760		13,355		34,460			171,000	616,215
1898	36		c 60,750		75,235		(d)		81,839		26,244		10,925		54,138		293,138	452,000	605,269
1899			c 79,720		167,889		(d)		82,766		25,722		12,964		21,060		16,011	104,000	406,132
1900			c 90,379		112,010		(d)		52,535		14,903		25,224		32,450		30,065	146,000	357,566
1901			108,959		94,611		26,267		70,894		29,340		14,358		14,300		43,942	129,000	402,671
1902	35		116,745		200,262		28,862		66,899		34,305		23,451		8,882		45,223	131,000	524,629
1903	34		59,421		408,875		26,164		58,811		63,260		25,203		12,169		218,038	313,000	871,941
1904	34		87,955		289,772		23,371		42,202	1,344,656	47,898		22,076		8,364		36,696	120,000	558,334
1905	34		158,126		230,736		28,238		52,125	1,015,215	42,983		23,474		5,336		95,346	187,000	636,364
1906	38		158,189		428,915		44,433		64,019	806,863	62,305		21,299		6,657		188,207	296,000	974,024
1907	35		31,928		110,600		26,302		112,393	854,134	37,666		26,908		10,510		234,846	310,000	591,153
1908			33,833		117,242		23,218		58,672	792,485	14,951		26,323		5,890		312,775	360,000	592,904
1909	38		25,097		274,501		35,867		66,538	180,130	8,698		45,823		31,586		122,404	223,000	610,514
1910			21,643		160,933		19,098		40,164	786,762	35,761		35,998		34,597		62,341	164,000	410,535
1911	42		24,177		175,287		33,312		60,139	1,038,474	49,498		28,327		55,577		148,356	284,000	574,673
1912			53,168		203,739		34,099		50,454	968,640	48,209		34,173		26,661		311,254	420,000	761,757
1913	40		35,292		141,214		40,352		94,456	992,509	46,640		25,549		29,061		352,770	463,000	765,334
1914	34		25,124		84,279		30,948		30,661	890,022	43,174		26,242		6,951		158,276	188,000	405,655
1915	31		62,636		95,938		41,082		40,282	448,466	21,899		23,753		3,692		29,627	74,000	318,909
1916	25		29,723		35,939		50,937		61,188	371,278	17,975		14,754	(e)	(e)	65,000	60,224	84,000	270,740
1917	19	92,376	20,789	11,333	23,546	43,234	52,816	11,965	61,970	458,863	24,921	33,500	17,898	1,648	1,580	9,876	9,145	32,000	212,665
1918	13	33,811	21,319	6,812	27,302	17,853	36,271	5,167	33,733	(c)	(c)	4,556	7,386	2,094	3,688	10,434	18,618	18,000	148,317
1919	14	17,335	7,332	3,270	12,900	25,765	60,371	2,118	19,058	243,239	23,422	15,750	8,438	(e)	(e)	44,993	73,603	52,730	205,124
1920	13	(f)	(f)	21,570	f 18,750	49,260	98,400	3,280	15,620	393,490	37,496	17,970	16,946	(e)	(e)	6,050	10,548	17,750	197,760
1921	11	(f)	(f)	f 14,300	f 22,625	14,140	61,920	5,560	62,293	372,030	28,137	(e)	(e)	(e)	(e)	12,540	18,624	11,060	193,599

a Includes production at Bridgeport, Greenwich, Niantic, and Sterling.
b Includes production at Greenwich and Sterling.
c Reported as "rough stone" and probably includes rough monumental stone.
d See "Rough building" stone.
e Included under "Other."
f Rough stone included under dressed.

RHODE ISLAND.

The granite industry of Rhode Island centers around Westerly, Washington County. Quarries were opened in this district as early as 1843, according to the report of the Tenth Census (1880), but it was after 1850 before the industry was fairly begun. In Providence County a quarry at Diamond Hill was opened in 1840, and one at Cranston in 1820. A quarry was opened at Newport, Newport County, in 1855.

There were 35 operators of quarries in 1889, and but 6 in 1921, aside from producers of crushed stone. The chief product of the Westerly quarries is monumental stone, and for this reason there was not so large a decrease in output in the five years 1917–1921 as was shown by the States where building stone is a considerable factor. A number of quarries have combined during the last few years.

Operators of granite quarries at Westerly, Washington County, R. I., in 1921.

Firm name.	Use.
New England Granite Works	Buildings, monuments, mausoleums.
Smalley Pink & Red Westerly Co	Monuments, paving blocks, rubble.
Smith Granite Co	Do.
Sullivan Granite Co.[a]	Monuments.
Westerly Blue Quarry Co	Monuments, paving blocks.
Westerly Pink Granite Co	Monuments.

[a] Operates the Crumb, Klondike, Joseph Newall & Co. (Dalbeattie), and John B. Sullivan quarries.

The operators of quarries for crushed stone were as follows:

Bristol County:
- L. H. Callan, Bristol.

Newport County:
- Peckham Bros. Co., Middletown (conglomerate, "puddingstone").
- City of Newport, Newport.
- J. K. Sullivan, Newport.
- J. F. Sullivan, Newport.

Providence County:
- Central Falls Stone Co., Central Falls (sandstone).
- Jos. McCormick, East Providence (sandstone or "bluestone").
- Thomas J. Quinn, Ashton (granite).
- Iron Stone Trap Rock Co., Woonsocket (cumberlandite, an ilmentite-magnetite rock).

Granite produced in Rhode Island, 1860–1921.

Year.	Number of plants.	Building.				Monumental.				Paving blocks.		Curbing and flagging.		Crushed.		Other.		Total.	
		Rough.		Dressed.		Rough.		Dressed.											
		Cubic feet.	Value	Cubic feet.	Value.	Cubic feet.	Value.	Cubic feet.	Value.	Number.	Value.	Linear feet.	Value.	Short tons.	Value.	Short tons.	Value.	Short tons (approximate).	Value.
1860																			$6,800
1880	17																	114,000	623,000
1887																			a 15,000
1888																			b 161,836
1889	37	2,554,450	$277,200					110,310	$588,199	781,765	$45,817	152,000	$20,000					242,000	931,216
1891																			750,000
1892																			600,000
1893																			509,799
1894											115,000								1,211,439
1895											49,255								968,473
1896			(c)		$199,487		d 90,219		366,840		50,851				$30,000		$8,880	100,000	746,277
1897	17		(c)		209,355		d 42,706		316,585		51,646		5,150		3,000		1,122	75,000	629,564
1898	15		(c)		40,987		d 43,505		204,739		19,510		3,488		1,920		6,093	35,000	320,242
1899			(c)		151,521		d 73,866		145,001		16,147		3,360		4,915		5,318	40,000	400,128
1900			(c)		120,428		d 70,800		232,144		13,382		3,461		3,483		618	35,000	444,316
1901			9,722		160,190		92,974		198,831		27,666		2,456		6,676		3,183	37,000	501,698
1902	19		18,798		120,767		111,752		438,967		14,657		5,638		15,410		8,634	60,000	734,623
1903	20		9,890		149,114		111,458		360,043		37,984		12,275		20,628		8,899	68,000	710,291
1904	19		12,643		214,599		118,236		153,930	1,138,190	47,823		2,725		130,573		4,423	188,000	684,952
1905	17		7,050		75,688		134,063		203,267	1,503,794	82,641		4,752	52,821	44,531		4,372	85,000	556,364
1906	16		10,310		184,614		159,525		171,700	834,001	42,532		4,100	56,262	44,783		5,248	84,000	622,812
1907	18		8,125		172,041		172,396		200,573	1,643,360	85,091		50	27,540	31,030		4,842	83,000	674,148
1908			5,272		71,613		149,638		262,376	567,416	29,651		976	29,051	31,314		5,634	67,000	556,474
1909	26		45,501		218,089		176,565		314,237	1,051,681	52,004		5,955	103,831	119,100		1,602	169,000	933,053
1910			16,439		43,140		166,306		185,079	868,088	40,411		11,530	50,165	57,797		788	92,000	521,490
1911	17		17,576		387,458		184,634		186,095	1,493,887	114,293		13,164	41,082	54,112		411	140,000	957,743
1912			14,331		164,752		178,565		269,074	780,382	37,449		7,891	78,085	88,917		6,528	132,000	767,507
1913	15		38,631		67,041		154,453		230,440	1,128,581	66,018		11,000	58,660	69,496		5,296	114,000	642,375
1914	18		8,931		11,905		186,388		246,209	901,843	51,298		15,350	93,000	101,141		398	132,000	621,620
1915	19		24,830		60,552		211,846		98,170	822,243	58,721		15,819	175,000	219,532		2,295	237,000	691,765
1916	16		26,529		37,923		170,511		115,353	530,853	35,027		16,270	147,612	201,265		28,359	255,000	631,237
1917	12	(e)	(e)	e 53,729	e 138,310	f 222,648	f 255,856	(f)	(f)	330,393	21,142	18,800	10,980	28,358	48,509	2,638	2,982	59,000	477,779
1918	9	(e)	(e)	e 89,995	e 211,307	f 112,371	f 267,605	(f)	(f)	(g)	(g)	(g)	(g)	15,140	23,306	4,130	22,834	36,000	525,052
1919	10	(e)	(e)	e 4,715	e 12,235	f 121,058	f 322,686	(f)	(f)	(g)	(g)			25,922	67,427	4,000	24,520	40,503	426,868
1920	10	f 49,610	f 42,061	(f)	(f)	143,240	335,355	15,120	129,157	(g)	(g)			19,360	57,190	4,850	23,111	41,820	586,874
1921	10	f 15,400	f 34,903	(f)	(f)	118,080	267,395			261,000	21,850			35,570	99,278	520	1,533	49,840	424,959

a Production at Niantic.
b Production at Diamond Hill and Niantic.
c Reported as "rough stone" and probably includes rough monumental stone.
d See "Rough building."
e Rough stone included under dressed stone.
f Dressed stone included under rough stone.
g Included under "Other."

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GLOSSARY OF SCIENTIFIC AND QUARRY TERMS.

ACCESSORY MINERALS in granite are original constituents of the rock, found only in small, often only in microscopic quantity.

ACIDIC. A term applied to rocks in which silicic acid (silica) or quartz predominates.

ALLANITE. An opaque black mineral (silicate), brown in thin section, one of the primary less common accessory constituents of granite, which contains from 12 to 17 elements, including 6 of the rarer ones. For analyses see Dana, E. S., System of mineralogy, 6th ed., pp. 522–526, 1892.

ANTICLINE. A term applied to granite sheets or sedimentary beds that form an arch.

APLITE. Fine-grained granite, generally occurring in dikes and containing little mica and a high percentage of silica.

BASIC. A term applied to rocks in which the iron-magnesia minerals and feldspars with lime and soda predominate, such as diabase or basalts.

BLACK HORSE. Term used by quarrymen to denote a dark biotite gneiss in contact with the granite.

Blind seams. Quarrymen's term for incipient joints.

Boulder quarry. One in which the joints are either so close or so irregular that no very large blocks of stone can be quarried.

Channel. A narrow artificial incision across a mass of rock, which, in a granite sheet, is made either by a series of contiguous drill holes or by blasting a series of holes arranged in zigzag order.

Cleavage, when applied to a mineral, designates a structure consequent upon the geometric arrangement of its molecules at the time of its crystaliliza-tion.

Close-jointed. A term applied to rock containing joints that are very near together.

Crocus. A term used in some quarries to denote gneiss or any other rock in contact with granite.

Crush border. A microscopic granular structure sometimes characterizing adjacent feldspar particles in granite in consequence of their having been crushed together during or subsequent to their crystallization.

Cut-off. Quarrymen's term for the direction along which the granite must be channeled, because it will not split. Same as "hard way."

Dendrites. Plantlike crystallization of iron or manganese oxides on the surfaces of fissures in any rock or mineral. Frost crystals on window panes are of like character.

Dike. A mass of granite, diabase, basalt, or other rock which has been erupted through a narrow fissure.

Dimension stone. A term applied to stones that are quarried of required dimensions.

Dip. The inclination from the horizon, given in terms of degrees, of a sheet, joint, heading, dike, or other structural plane in a rock.

Drift. Sand and boulders deposited by the continental glacier.

Drumlin. Oval hillock of clay and boulders formed beneath the ice sheet of the glacial epoch.

Erosion. The wearing away of portions of a rock by such natural agencies as stream or ice action.

Exfoliation. The peeling of a rock surface in sheets owing to changes of temperature or to other causes.

Faulting. The slippage of a rock mass or masses along a natural fracture.

Flow structure. The parallel arrangement of the minerals in granite or other igneous rock in the direction of its flowage during its intrusion.

Geode. A rock cavity lined with crystals. Geodes in granite are attributed to steam or gas bubbles.

Grain in granite is practically the direction in which the stone splits "next easiest," the "rift" being that in which it splits most readily.

Grout. A term applied to the waste material of all sizes obtained in quarrying stone.

Grow-on. Quarrymen's term to designate the place where the sheet structure dies out, or the place where two sheets appear to grow onto one another.

Hard way. The direction at right angles to both rift and grain in which granite does not split readily. (See Cut-off.)

Heading. A collection of close joints.

Heading seam. See Joints.

Hematite. An oxide of iron (Fe_2O_3), which, when scratched or powdered, gives a cherry-red color.

Igneous. A term applied to rocks that have originated in a molten condition.

JOINTS. More or less steeply inclined fractures which cross the granite sheets and which are attributed to various stresses.

KAOLIN. A hydrous silicate of alumina derived from the alteration of feldspar.

KAOLINIZATION. The process by which a feldspar passes into kaolin.

KNOTS. A term applied by quarrymen to dark-gray or black objects, more or less oval or circular in cross section, which are segregations of black mica or hornblende formed in the granite while in a molten state. English quarrymen call them "heathen."

KNOX HOLE. A circular drill hole with two opposite vertical grooves which direct the explosive power of the blast.

LEWIS HOLE. An opening made by drilling two or three holes near together and chiseling out the intervening rock.

LIMONITE. A hydrous oxide of iron ($2Fe_2O_3.3H_2O$); a hydrated hematite, which, when scratched or powdered, gives a brownish rust color.

MATRIX. The general mass of a rock which has isolated crystals; sometimes called groundmass.

METAMORPHISM. The process, partly physical, partly chemical, by which a rock is altered in the molecular structure of its constituent minerals and in their arrangement. Metamorphism may be regional, due to crustal compression, or contact, due to the intrusion of sedimentary rock by an igneous rock.

MILLIMETER. French decimal linear measure, the thousandth part of a meter or the tenth part of a centimeter. It is equivalent to nearly 0.04 inch, the meter being $39\frac{10}{27}$ inches.

MONOLITH. A column or monument of one stone.

MOTION. A term used in granite regions to designate small paving-block quarries.

OPHITIC. A term applied to microscopic rock texture to designate a mass of longish interlacing crystals, the spaces between which have been filled with minerals of later crystallization.

OREÏ. A term applied in the Quincy quarries to Quincy granite which has been rendered valueless by the alteration of its aegirite particles.

PEGMATITE. A very coarse granite occurring in irregular dikes or lenses in granites and some other rocks.

PHENOCRYST. A term applied to isolated crystals visible to the unaided eye and lying in the mass of a rock of igneous origin.

PLAGIOCLASE. A term applied to all those feldspars that are not potash feldspars.

PLUG AND FEATHERS. A quarrymen's term. The plug is a wedge, and the feathers are two short pieces of half-round iron whose curved sides fit the drill hole while their flat sides receive the plug. By driving the plugs in a series of holes a stone may be broken.

POLARIZED LIGHT. Light whose vibrations, unlike those of ordinary light, which are in all directions, are in only one plane. Polarized light is used in the microscopic study of rocks.

PORPHYRITIC. A term applied to rock texture to designate the presence of isolated crystals in a general mass (matrix or groundmass) of finer material.

PSEUDOMORPH. Signifies false form and designates a crystal in which, owing to various chemical changes, the original mineral has been more or less replaced by others. The form of the crystal no longer corresponds to the mineral.

Quartz monzonite. Technical designation for a granite in which the percentages of soda-lime feldspar and of potash feldspar are nearly the same or in which the former exceeds the latter. In ordinary granites the amount of soda-lime feldspar is relatively small.

Random stone. A term applied by quarrymen to quarried blocks of any dimensions. (See definition of dimension stone.)

Rift. A quarrymen's term to designate an obscure microscopic cleavage in granite which greatly facilitates quarrying.

Run. A term used by quarrymen in connection with "rift," apparently to denote the course of the deflection of the rift due to gravity, strain, or other not yet understood cause. In southern and western quarries the grain is called the run.

Salt horse. Quarryman's term for aplite or other useless rock.

Sand seams. Quarry term for more or less minute veins or dikes of muscovite (white mica) with some quartz, in cases also with feldspar.

Sand streaks. Same as sand seams.

Sap. Quarrymen's term for ferruginous discoloration along sheet or joint surfaces.

Schist. A rock made up of flattish particles arranged in rough parallelism, some or all of which have crystallized under pressure.

Schistosity. The quality of being like a schist.

Seam. Quarrymen's term for joint.

Secondary minerals. Minerals whose presence is due to the alteration of the original minerals.

Sedimentary. A term designating those rocks that consist of particles deposited under water.

Segregation. The scientific term for "knot," a collection of material separated from other material. A vein of segregation is one formed by the filling of a fissure with mineral matter originating in the surrounding rock.

Sericite. A more or less fibrous form of muscovite (potash mica), often resulting from the alteration of feldspar.

Shakes. Quarrymen's term to designate a somewhat minute close-joint structure, which forms along the sheet surface as a result of weathering.

Sheet quarry. A quarry in which the granite lies in sheets, crossed by wide-spaced steep joints.

Slickensides. The polished and grooved faces of a joint or bed caused by motion and friction.

Strain sheet. Quarrymen's term for granite sheets produced by present compressive strain.

Stratified. A term applied to rock consisting of originally horizontal beds or strata.

Strike. The direction at right angles to the inclination of a plane of bedding, a sheet, or joint, etc.

Stripping. The material (sand, clay, soil, etc.) overlying a rock of economic value, which must be removed before quarrying.

Specific gravity. The weight of a rock or mineral compared to that of a body of distilled water of the same bulk.

Subjoint. Minor joints diverging from or parallel to the regular joints.

Syncline. A geologic term for the trough part of a wavelike sheet or bed of rock.

Till. A mixture of clay and boulders deposited by glaciers.

TILLITE. Special name for the material of the till. The evidence that the clay and pebbles or boulders are of glacial origin is in the parallel striation of the pebbles or boulders owing to their having been rubbed against a rock while fixed in the moving ice.

TOEING IN. Quarrymen's term for the wedging in of the end of a granite sheet under an overhanging joint, probably in consequence of the faulting of the sheets along the joint. It is also applied to the overlapping of lenticular sheets.

"TOENAILS." Curved joints intersecting the sheet structure, in most places striking with the sheets, in some differing from them in strike 45° or more.

TWIN CRYSTALS. Two adjacent crystals which have formed with the poles of their main axes in opposite or different directions.

WEATHERING. The decomposition of a rock owing to the action of the weather.

WHITE HORSE. Term used by quarrymen to denote a light-colored gneiss, aplite, or pegmatite.

WOLLASTONITE. A mineral consisting of silica 51.7 per cent and lime 48.3 per cent ($CaSiO_3$). It commonly results from the metamorphism of calcareous rock or marble where in contact with an igneous rock.

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